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A PRELIMINARY STUDY OF THE INFLUENCE OF CHLORIDES ON THE GROWTH OF CERTAIN AGRICULTURAL PLANTS.[1]

W. E. TOTTINGHAM.

INTRODUCTION.

Investigations on the nutrition of higher plants early led to the conclusion that carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, and iron are essential to their growth. Less certainty has attended our knowledge of the rôle of sodium, silicon, and chlorine in plant growth. Various observations, however, seem to have led to general belief that, altho exerting beneficial effects under certain conditions, these elements are unessential for most plants. As none of the seed plants tested have been deprived of chlorine thru successive generations, it appears that the necessity of this element has never been adequately investigated. Apart from this relation, however, it is certain that some seed plants contain much more chlorine than others, that some can endure much higher chloride concentration about their roots than is possible for others, and that differences in the amount of this element in the soil are frequently accompanied by characteristic differences in growth and development. In view of these considerations it appears to be

[1] Botanical contribution from the Johns Hopkins University, No. 54. This work was done partly in the Department of Agricultural Chemistry of the Wisconsin Agricultural Experiment Station and partly in the Laboratory of Plant Physiology of the Johns Hopkins University. The writer is indebted to Professors E. B. Hart and B. E. Livingston, of these respective institutions, for facilities and advice extended to him in the course of these investigations. Professor Livingston has also aided greatly in the preparation of this paper. Received for publication June 1, 1918.

important to investigate rather fully the effects of chlorides in nutrient media and to reconsider their relative importance in fertilizer practice.

The literature of this subject presents considerable evidence that beneficial effects upon plant growth may be expected to follow the application of chlorine to the soil in the form of sodium chloride, or common salt. For example, Griffiths (21, p. 250–256)[2] refers to the use of salt as a fertilizer from ancient times, and states that about 250,000 tons of the substance are used annually in the United Kingdom for agricultural purposes. Hall (22, p. 334, 357) mentions the English practice of top dressing mangolds, potatoes, and barley with salt. In the last instance, this was done for the purpose of stiffening the straw. He ascribes the benefits of this practice to liberation of potassium from feldspars. Cameron (12, p. 108) says: "In spite of the fact that it does not contain a conventional plant food, sodium chloride appears to produce results quite similar to those produced by the usual fertilizer salts. Its use has been followed generally by an increased yield of crop, but occasionally by a decreased one, and it appears not improbable that further investigation would show sodium chloride to have a considerable value as a fertilizer." Other authorities express different opinions. Thus, Hilgard (29, p. 76) regards the usefulness of common salt in fertilizers as entirely subordinate, and Wheeler (75, p. 246–249, 334, 357) treats chlorine as unessential for plants. These writers consider 0.10 to 0.25 percent of NaCl in the soil as sufficient to inhibit the growth of cultivated plants, the effect depending upon the dryness of the soil.

The available evidence regarding the effects of chlorides upon plant growth would seem to justify further investigation. For several years the writer has been interested in this problem, and the present paper is a report of the results already obtained.

I. Review of Previous Experimentation.

IS CHLORINE ESSENTIAL?

Early in the development of the water-culture method in the study of plant nutrition certain investigators obtained results which led them to consider chlorine essential for the complete development of the buckwheat plant. The chief investigation in this field is that of Nobbe and Siegert (48), who observed peculiar physiological disturbances in buckwheat plants grown in chlorine-free nutrient solutions. The apparent need for chlorine first became noticeable at the fruiting stage, when it appeared that KCl and $CaCl_2$ were superior to NaCl and $MgCl_2$ as sources of this element. Certain phenomena of

[2] References are to "Literature cited," p. 28.

growth observed in these experiments led to the conclusion that chlorine functions in the translocation of carbohydrates. Wagner (74) and Aschoff (2), employing somewhat different nutrient solutions and methods of culture, arrived at directly opposed conclusions regarding the necessity of chlorine for the growth of maize; and in the hands of Beyer (4), peas produced seed, but oats failed to do so, when grown in a chlorine-free nutrient solution. The results of these early investigations were decidedly conflicting and they can scarcely be expected to have approached finality, having been conducted when the problem of the physiological balancing of salts in nutrient solutions was as yet hardly appreciated.

In the Laboratory of Plant Physiology of the Johns Hopkins University[3] buckwheat has been reared repeatedly to the production of apparently perfect seeds, employing as a nutrient medium the three-salt solution of Shive (57). These results are in agreement with those of Shulov (59), who found chlorine unessential for buckwheat. Furthermore, from the results of extensive series of water and sand cultures, Prianishnikov (52) concludes that "the generally accepted opinion of the usefulness of chlorine as such for plant life is not corroborated."

From the preceding brief review it appears that chlorine, aside from the small content of the seed, is unessential for the complete development of buckwheat, and probably also for others of the common seed plants.

STIMULATING EFFECTS OF CHLORIDES

As regards the germinating stage of growth, it should be noted that Jarius (33) observed stimulation of several species of seeds by soaking in 0.4 percent solution of NaCl, while other salts tested were not so effective. Plate (51) has reported that the stimulating effects of certain chlorides upon the root and sprout growth of oats during germination were markedly different from those of the corresponding nitrates. The effectiveness of the chlorides in decreasing order is given as follows: NaCl, KCl, RbCl, LiCl, CsCl.

As regards the complete cycle of growth, early English experiments with the small grains (23) gave results favorable to the use of common salt as a fertilizer. Increases of 1.4 to 11.4 bushels of grain per imperial acre followed the application of salt at rates of 300 pounds or more, and in some cases the weight of grain per bushel and yield of straw were increased also. On the other hand, results obtained by

[3] Incident to investigations of Earl S. Johnston. The Johns Hopkins University Circular, March, 1917, p. 211–217.

Sir John Lawes (39) led him to oppose this practice. To one of two plots which had been continuously cropped with wheat since 1843 he added salt at the rate of 300 pounds per acre per year, from 1851 to 1853, in addition to the common dressing of mixed minerals and ammonium salts added to the two plots. There was no appreciable variation in the yields from the two plots, either during this period or in the succeeding ten years. In cooperative field tests of common salt at the rate of 300 pounds per acre Voelcker (72) obtained an increased yield of barley in one region but a decreased yield in another. Tests conducted by Shelton (55) in the United States led to unfavorable deductions, despite gains in yield. In one of these tests an application of 300 pounds of salt increased the yield of wheat 4 bushels per acre and produced a persistent brightness of the straw. Brooks and Thomson (8) applied 250 and 400 pounds of chloride of potassium in comparison with equal amounts of the sulfate, as constituents of a complete fertilizer, and found the two equally effective with grains and grasses, but clover was injured by the chloride.

It seems to have been a rather general practice in Great Britain to top-dress grassland with common salt. Investigations conducted by the Royal Agricultural Society (13) led, however, to adverse recommendation regarding such practice. Applications of 500 pounds of salt per acre to soils which were mostly clays, in various parts of England, produced no appreciable effect upon either the quantity or quality of grass produced. It may be noted, however, that Voelcker (70) had previously obtained increased yields from the use of salt in similar tests. In this country Jones (35, p. 71) observed nearly 100 percent increase in weight of meadow fescue (*Festuca ovina*) on land which had received salt at rates of 200, 300, 500, and 1,000 pounds per acre to kill hawkweed (*Hieracium aurantiacum*).

The mangold and the sugar beet, closely related genetically and supposed to have originally inhabited the salty sands of the seashore, are generally stimulated to greatly increased production by sodium chloride. Thus, Voelcker (68), altho he had previously failed to obtain an increase of the crop on a stiff, calcareous clay, applied common salt to mangolds on a light sandy soil at rates of 100, 300, 500, and 700 pounds per acre, and obtained increased yields from the two medium applications. The maximum increase over the yield from untreated plots amounted to over 50 percent and was obtained from the 500-pound application. This investigator believed that the salt functioned by retarding the development of the plant. More recently Voelcker (73) obtained, from applications of salt up to 600 pounds per acre on a sandy soil, supplementary to farm manure and min-

eral fertilizers, much greater yields of mangolds than were obtained where the salt was omitted. Since $NaNO_3$ was included among the mineral fertilizers applied, Voelcker attributed the effects of the NaCl specifically to its chlorine content. Lawes (39) had earlier obtained progressively smaller yields of mangold as he increased the application of salt from 500 to 1,000 pounds per acre and concluded that its use was unjustified, but his applications seem to have been excessive.

Among American investigations, Lyon and Wiancko (46) found the use of 600 pounds of common salt per acre upon a deep, medium loam without effect on either the yield or the percentage of sugar of the sugar beet. Brooks and Thomson (6), employing the salts at rates of 250 and 400 pounds per acre, obtained a slightly higher yield but a diminished percentage of sugar from KCl as compared with K_2SO_4 in one season, but found the two salts equally effective in another season.

As to other crops, the yield of turnip has responded variably to the application of common salt in English trials (69). The same is true of the use of KCl in American experiments. Thus, at the New Jersey station (81), 160 pounds per acre of KCl in mixed fertilizers was less productive than an equal quantity of K_2SO_4, while at the Massachusetts station (9) 250 pounds of KCl produced a greater yield of crop than did an equal quantity of K_2SO_4, the salts being employed in a complete fertilizer ration.

The cabbage seems to respond decidedly to the application of chlorides under certain conditions. Thus, Dyer (17), operating upon a light clay soil in a season when drouth occurred at the critical growth period of the plant, obtained practically a doubled yield by applying 300 pounds per acre of NaCl, in addition to the usual ration of manure, sodium nitrate, and phosphates. Contradictory results were obtained by Brooks and his coworkers (7), who found KCl to give greater yields than K_2SO_4 in some cases, but smaller yields in others, with a tendency for the former salt to produce soft cabbage heads. As a result of their tests upon medium clay loam, the latter investigators state that "clearly, climatic conditions have an important influence in determining the manurial effects of these salts," and "in hot dry seasons the differences between the chloride and sulfate are small on the cabbage."

At the Massachusetts station KCl has been compared with K_2SO_4 as a source of potassium upon a variety of field and truck crops. In the results of three years, summarized in 1904 (10), the chloride was superior with late crops while the sulfate proved best for early crops. The investigators remark that "In soils of fair retentiveness of water

only beets were decidedly best on KCl" and "Chlorides increase the wateriness and tend to delay the maturing of crops." In applications of 250 pounds of potassium salts with bone meal (11), berries and garden plants did equally well on the two salts, while the soybean yielded poorly from the chloride.

Tests conducted by Gonehalli (19) upon mango trees in the Province of Bombay, British India, gave striking results. Addition of common salt to the soil about the roots at the rate of 10 pounds per tree gave an increase of nearly 150 percent in the number of fruits produced the following year, as compared with the yield from untreated trees. The same writer reports marked increases in the yields of cocoanuts and rice from applications of salt.

Probably the common potato has received more attention than any other crop relative to its response to the application of chlorides, especially in comparisons of KCl with K_2SO_4 as a source of potassium. As regards the numerous experiments on this question in the United States, the published descriptions of the tests are often so meager as to make conclusions uncertain. This is especially true of those cases in which the method of determining starch is not given, for, as will appear in part 2 of this paper, the use of specific gravity values for this purpose is unreliable.

In an early trial of common salt upon various English farms (71) at the rate of 400 pounds per acre, both alone and as part of a complete fertilizer ration, the treatment either resulted in toxicity to the potato or produced no effect. Equal yields of tubers having the same percentage of starch were obtained by Pfeiffer and others (49) from the use of KCl and K_2SO_4. About 200 pounds of each salt per acre were applied, in a complete fertilizer with lime, to two varieties of potato in confined portions of an unproductive sandy soil. The use of $MgCl_2$, however, in conjunction with K_2SO_4, seriously depressed the yield of tubers and and somewhat decreased their starch content. Favorable effects upon yield from the use of 600 pounds of KCl per acre led Emery (18) to the extreme statement that "K_2SO_4 is not desirable for the potato when KCl is obtainable."

Investigations of these two salts with two varieties of potato and two types of soil in New Jersey (80) resulted in a greater yield with KCl, altho the tubers were more watery and of poorer quality than those produced with K_2SO_4. Jenkins (34) applied 63 to 240 pounds per acre of either KCl or K_2SO_4 in a complete fertilizer ration on different farms. Neither salt was decidedly superior as to yield of tubers, but the crop which received KCl contained 0.5 percent more water than that produced by K_2SO_4. In a dry season Taft (63) ob-

tained slightly lower yields from KCl than from K_2SO_4, each salt having been applied at the rate of 320 pounds per acre in a complete fertilizer ration. Potassium salts at the rate of 400 pounds per acre were applied with acid phosphate and sodium nitrate to two varieties of potato and two types of soil in Vermont (31). Without sodium nitrate the chloride of potassium produced tubers richer in water and poorer in starch, as compared with those produced by the sulfate. This difference disappeared with the complete fertilizer ration.

Davidson (15) added 100, 200, and 300 pounds of potassium salts per acre in a complete fertilizer applied to three varieties of potato, in Virginia. As an average of all the plots which received each salt the tubers produced by KCl were reported to contain 0.7 percent less dry matter, but 0.6 percent more starch in the dry matter, than those produced by K_2SO_4. Brooks and his coworkers (79) have devoted special attention to the potato in tests of the relative values of muriate and sulfate of potash. The Beauty of Hebron variety of potato seems to have been chiefly employed by Brooks, who extended his investigations to several regions and soil types. Potassium salts were applied at rates of 160 to 263 pounds per acre in a complete fertilizer. Samples of the tubers were tested for cooking qualities by various families. In a majority of cases the results from K_2SO_4 were superior to those from KCl as to yield, composition, and quality. The tubers produced by the former salt were drier and superior in whiteness, mealiness, and flavor, as compared with those produced by the chloride.

TOXIC EFFECTS OF CHLORIDES.

Loew (45) ascribes to sodium chloride, in sufficient concentration, a depression of photosynthetic formation of carbohydrates by leaves and a decrease in the percentages of sugar in the sugar beet and of starch in the potato. Harter's comparison (26) of his own results with those of other investigators, relative to the growth of seedlings in salt solutions, indicates that lupine and maize are injured at lower concentrations of NaCl than is wheat. In Harter's investigations this salt was not toxic to wheat below a concentration of about 300 parts per million in the solution.

Takeuchi and Ito (64) found calcium and magnesium chlorides injurious to the rice plant when 0.1 percent of each was applied to a rich loam in pot cultures, but 0.05 percent was not particularly injurious.

Applying various sodium salts to a sandy soil in pot culture, supplementary to a complete fertilizer containing K_2CO_3, Suchting (62) observed a depression in the yield of potato tubers and also in the

percentage of starch in these organs from the use of NaCl. The application of NaCl amounted to 580 pounds per acre foot (4,000,000 pounds) of soil. Altho it was found that chlorine migrated into the tubers, there was no apparent correlation between such migration and the extent of injury observed.

At the Rhode Island station (76), the chlorides of calcium, magnesium, and ammonium were added to completely fertilized soil in large pots. With a soil of acid reaction, calcium and ammonium chlorides were decidedly toxic to cereal grains and to the potato, but magnesium chloride was not injurious in the concentration tested. The toxicity of the former salts was overcome by liming. It was concluded from these results that all of the apparently conflicting evidence regarding poisonous actions of chlorides upon plants, when these salts are applied in moderate quantities, might be harmonized upon the basis of differences in the chemical reaction of the soil.

In extensive investigations on the effects of chlorides in alkali soils, Harris (25) has found sodium chloride, at 0.2 percent concentration in the soil, to reduce the germination of wheat by half. He finds this to be the most toxic of the several common chlorides investigated. Harris found the toxic effect of chlorides to be only half as great in sand as in loam, the effect in dry soil being less than in wet. The limit to productiveness of the soil is set by this investigator at 0.3 percent of chlorides in loam and 0.2 percent in coarse sand.

SPECIAL PHYSIOLOGICAL RESPONSES TO CHLORIDES.

The responses of plants to the presence of chlorides in the nutrient medium may be divided into two apparently distinct classes, namely, those which affect the form of the plant (morphological) and those which influence its composition (compositional).

Marked changes in structure and transpiring power of plants under the influence of sodium chloride have been observed by Harter (27) with wheat. Employing a saline soil in which NaCl formed about 70 percent of the total salts, he diluted this with garden loam, so as to obtain soils containing 1.4, 1.0 and 0.7 percent of NaCl, on the basis of dry weight. Tumbler cultures of these soils were sealed with paraffin to permit comparative transpirational measurements by weighing. In general, the epidermal cells of the plants in the saline soils were smaller than those of the control plants grown in the loam soil, and the cuticle was thicker in the former case, the leaf surface developing a conspicuous amount of bloom. Leaves from cultures so modified lost but one-third to half as much water, relative to dry weight, as did leaves from the control culture. On the other hand,

leaves from cultures in which the saline content of the soil was insufficient to affect the amount of bloom on the leaves showed 10 to 20 percent higher transpiration rate per unit of leaf area than similar leaves from the control plants.

As to the exterior form of the plant, Hansteen (24, p. 318) observed, with water cultures, that solutions containing chlorides, as compared with other salts, produced wheat plants with longer roots and shorter leaves. He considered this condition to be a response to a decrease in the rate of water absorption, both brought about by an increased absorption of the chlorine ion.

The chemical composition of the plant, as this may be influenced by the addition of chlorides to the soil, seems to have been investigated but little, save in the case of the sugar beet and potato. Some of these effects have been pointed out already (Brooks and Thomson, 6, 10; Pfeiffer *et al.*, 49; Hills, White, and Jones, 31; Davidson, 15; Brooks, 79; Suchting, 62). According to Bolin (5) NaCl and KCl applied with the usual fertilizers in Sweden, while increasing the total crop, appeared to increase the wateriness of the sugar beet and potato. De Ruijter de Wildt and his coworkers (16) found an application of 267 pounds of common salt per acre without effect upon the percentage of sugar in the sugar beet, but an excessive salt content of the soil (due to flooding with sea water) depressed the sugar content. They also note some disturbances in the distribution of nitrogen compounds.

2. Experimentation.

General Considerations.

The plan of the work here described comprehended both qualitative and quantitative investigation of the responses of various agricultural plants to the application of chlorides in various nutrient media. As culture media the well-known nutrient solution of Knop (37) and also common soil were employed in the greenhouse, and certain experiments were conducted upon field plots. As indicated by the preceding review of previous experimentation, the effects of substances added to the soil in field experiments are liable to obscurement by uncontrolled climatic factors, as well as by soil peculiarities. Indeed, one of the prime desiderata of future experimentation in plant nutrition is the development of apparatus for the control of the chief climatic factors, to supplement the more refined methods of control now developed with artificial nutrient media.

The chlorides of potassium and sodium were chiefly used as sources of chlorine. Either the sulfate or nitrate of potassium, depending

upon the formula of nutrients employed, was replaced partly or wholly by potassium chloride, and sodium chloride was applied either alone or supplementary to a complete nutrient mixture.

The plants grown were chosen with a view both to their agricultural importance and to the including of a considerable range of genera, with supposedly different physiological requirements. Perhaps the most convenient descriptive treatment of the experimentation may be based upon the species of plants used, and the discussion to follow will conform to this plan. Results from preliminary cultures led to emphasis being placed upon the so-called root crops. These preliminary cultures were conducted with Knop's solution and Tottingham's (65) modification of the same, found somewhat better for the growth of young wheat plants. Inasmuch as the usual amount of $MgSO_4$ was replaced either wholly or in part by $MgCl_2$ and $Mg(NO_3)_2$ in these cultures, they must be considered as more or less deficient in an important nutrient element, namely, sulfur. Wheat, garden peas, and red clover were brought to a stage of apparent vegetative maturity in the various solutions employed, altho only the peas produced seed and neither of the other plants blossomed, even in the complete nutrient solution. Suffice it to state that the $MgCl_2$ was very toxic to the clover, but not to the other plants, as evidenced by the yields of dry matter. The remarkable fact about these cultures was that the maximum application of chloride led to a greatly increased length of roots. This increase ranged from 120 percent in the case of peas to 180 percent in the case of clover. Some corresponding increase in production of dry matter of the roots accompanied the greater elongation of these organs. That the elongation was due in part to the removal of a suppressing effect of $MgSO_4$ is evidenced by the fact that substitution of $Mg(NO_3)_2$ for the latter gave increased developments of roots, but the effects were not so pronounced as those produced by the chloride. In view of these results it appeared advisable to devote special attention to those plants in which the root comprised the major portion.

WHEAT.

Thus far, wheat (*Triticum sativum*) has been studied by the writer only in water culture, employing as a basis Knop's solution having a total salt concentration of 0.2 percent (osmotic value about 0.9 atm.) with KH_2PO_4 as the source of phosphorus. Uniform seedlings of the Fulcaster variety obtained by Shive's method (58, p. 343) were mounted by the method of the writer (65, p. 173–175) in

cylindrical glass jars of approximately 425 c.c. capacity (pint jars of the Mason pattern), each jar being covered with heavy brown paper to exclude light. The chlorine ion was introduced by replacing the KNO_3 of Knop's solution partially or completely with KCl, by adding NaCl to the unmodified solution, or by replacing the KNO_3 wholly with KCl and adding $NaNO_3$, molecularly equivalent concentrations of these various salts being employed.[4]

Six different solutions were employed (see the column headings of Table 1), four cultures of each, each culture having three seedlings. During the growth of this culture series (February 16 to March 24, 1917, at Baltimore) the cultures stood on a rotating table of the type used by Shive (58, p. 344, 345), to equalize the aerial environment for all cultures of the series. The nutrient solutions were renewed after intervals of three days. At the end of the growth period the roots were washed and their approximate maximal lengths were measured. They were then severed from the tops and both roots and tops were weighed after drying at about 105° C. The volume of solutions absorbed by the plants during the last eight days of growth were also measured in this series.

As partial indices to the climatic conditions attending growth, temperature records were obtained by a thermograph placed in shade beside the rotating table, and the evaporating power of the air was determined by means of a white spherical porous-cup atmometer (43), the readings being reduced to those of the Livingston spherical standard. The average daily maximum temperature was 29.3° C., the average daily minimum was 16.9°, and the extremes for the period were 31° and 10 5°. The total corrected loss from the atmometer for the culture period was 648.6 c.c.

Data of yield, root length, and water absorption appear in Table 1. From the data in this table it appears that increasing amounts of KCl depressed slightly the yields of dry tops and roots, as well as the length of roots. On the other hand, while the additions of NaCl and $NaNO_3$ seem to have depressed the length of roots equally, both led to slightly increased yields of dry matter as compared with the other solutions. The maximal application of KCl and the use of NaCl were attended by increased water absorption in proportion to the dry tops, but these increases were not so great as that produced where $NaNO_3$ was supplied, relative to the dry tops of the plants.

[4] As here used the unmodified Knop's solution had the following volume-molecular partial concentrations of the respective salts: $Ca(NO_3)_2$, 0.0069; $MgSO_4$, 0.0025; KH_2PO_4, 0.0017; and KNO_3, 0.0029. Four or five drops of a dense suspension of $FePO_4$ were added.

The slight effects of chlorides upon this plant, as here shown, are in agreement with the extensive results of Trelease (66).

TABLE 1.—*Effect of chlorides introduced into Knop's nutrient solution upon the growth of young wheat plants therein.*

Data.	Solution 1, unmodified Knop's.	Solution 2, 0.01 of KNO_3 replaced by KCl.	Solution 3, 0.1 of KNO_3 replaced by KCl.	Solution 4, total KNO_3 replaced by KCl.	Solution 5, as 1 with addition of NaCl.	Solution 6, as 4 with addition of $NaNO_3$.
Dry weight of tops, mg.:						
Maximum	860	888	779	859	897	862
Minimum	750	693	726	626	761	742
Average	**799**	**811**	**750**	**744**	**821**	**823**
Dry weight of roots, mg:						
Maximum	232	248	221	252	256	238
Minimum	207	195	204	175	216	216
Average	**220**	**227**	**214**	**210**	**239**	**232**
Greatest root length, mm..						
Maximum	231	225	238	200	191	222
Minimum	200	216	200	153	178	178
Average	**215**	**220**	**218**	**186**	**185**	**195**
Water absorption, c.c.:						
Average per culture	**293**	**288**	**286**	**305**	**348**	**374**
Average per gram of dry tops	**367**	**325**	**380**	**410**	**423**	**456**
Average per decigram of dry roots	**133**	**116**	**134**	**145**	**145**	**162**

BUCKWHEAT.

The methods of culture applied to buckwheat (*Polygonum fagopyrum*) were those just described in connection with wheat, except that when the cultures were discontinued the leaves were severed at their junctions with the petioles and dried separately. This added procedure made possible a direct comparison of the rates of water absorption (as approximately measuring the transpiration ratio) with the dry weights of leaves. During the period of growth of these cultures (December 7, 1916, to February 6, 1917, at Baltimore), the climatic data obtained were as follows: Average maximum daily temperature 24.2° C., average daily minimum 15.2°, and extreme range from 30° to 8°. The corrected total evaporation for the period was 612.6 c.c., from the white spherical atmometer.

The data of this culture series appear in Table 2. Seed production is there expressed by an arbitrary method; 0 denotes that flowers only were produced; 1 denotes apparently immature seeds; and 2 denotes apparently mature seeds. From these relative scores an average value is shown for each nutrient solution.

TABLE 2.—*Effects of chlorides introduced into Knop's nutrient solution upon buckwheat grown to maturity therein.*

Data.	Solution 1, unmodified Knop's.	Solution 2, 0.01 of KNO_3 replaced by KCl.	Solution 3, 0.1 of KNO_3 replaced by KCl.	Solution 4, total KNO_3 replaced by KCl	Solution 5, as 1 with addition of NaCl.	Solution 6, as 4 with addition of $NaNO_3$
Dry weight of leaves, mg.:						
Maximum. . . .	1,293	1,454	1,319	1,096	1,079	1,168
Minimum. .	878	911	972	807	557	646
Average. . .	1,128	1,063	1,124	956	841	937
Dry weight of stems, mg.:						
Maximum. . .	1,332	1,552	1,419	1,480	1,253	1,307
Minimum.	1,091	1,022	1,151	955	525	771
Average. . .	1,181	1,199	1,273	1,135	936	1,101
Dry weight of roots, mg.:						
Maximum.	104	171	216	164	180	142
Minimum	117	135	139	118	46	88
Average. . .	154	154	173	131	119	114
Greatest root length, mm.:						
Maximum .	241	230	235	266	223	282
Minimum	190	177	196	137	142	150
Average .	214	211	216	192	179	192
Average water absorption, c.c.						
Per culture. .	248	225	238	210	160	200
Per gram of dry leaf	220	212	212	220	190	214
Per decigram of dry root.	161	146	138	160	135	176
Seed production score	1.2	1.2	1.0	.8	1.0	1.0

From Table 2 it is evident that the maximal applications of chlorine depressed the production of dry matter in leaves and roots in all cases. The dry weight of the leaf tissue was decidedly lowest where NaCl was present in the solution, and this particular solution also produced the least dry matter of stem and petiole, but root length was quite uniformly depressed in all cultures that received the maximal amount of chlorine. No significant differences in seed production were apparent.

With the exception of the culture which received NaCl the amount of water absorption per unit of dry matter in the leaves was quite constant. This particular salt seems to have caused a specific reduction in transpiration. The ratio of water absorption to dry weight of roots varied irregularly, but root length and water absorption per culture varied in a corresponding manner, greater absorption accompanying longer roots.

From these considerations it appears that the chlorine ion in these cultures produced disturbances evident as decreased root length, de-

creased production of dry matter of leaves and roots, and decreased water absorption per culture. In some of these ways sodium chloride appears to have produced specific effects, such effects being least production of dry matter in both leaves and stems and the only variation from uniformity in the ratio of water absorption to foliar dry matter.

On the basis of the theory of electrolytic dissociation (47, bk. 2, chap. 7), according to which the salts as here employed should be almost completely dissociated into their constituent ions, it seems difficult to conceive appreciable chemical or physical differences between the culture solutions of formulas 5 and 6, Table 2. Nevertheless, the buckwheat plants exhibited in solution 5, to which sodium chloride was added, a response markedly different from that observed in solution 6, which received the same amounts of sodium and chlorine (but supplied in different salts) as did the former solution. In view of the current chemical interest in the relative rôles of molecules and ions in reactions (1), the apparently specific effects of the sodium chloride molecule here observed surely merit further investigation.

RADISH.

A single series of soil cultures was conducted in the greenhouse at Madison with a small, round variety of radish (*Raphanus sativus*) designated as Earliest Scarlet Turnip. Miami silt loam was employed in cylindrical stoneware jars 12 cm. deep and 18 cm. in diameter (of 1 gal. U. S. capacity), capable of holding 5 kg. of air-dried soil. The latter was secured to a depth of 3 to 4 inches from the University of Wisconsin farm, and was passed through a wire screen having meshes 6 mm. square. It then contained about 15 percent of moisture, and analysis by the standard methods (78) showed it to have the following partial composition, upon the oven-dried basis: Total nitrogen, 0.15 percent; total phosphorus, 0.06 percent; total potassium, 1.83 percent; $CaCO_3$, 0.33 percent; humus, 1.38 percent.

The plan of fertilizing included both the substitution of KCl for K_2SO_4 in a complete fertilizer mixture and the supplementary addition of NaCl, chemically equivalent amounts of these salts being employed. Of the several salts the following amounts were employed per jar: 2.0 gm. $CaHPO_4 \cdot 2H_2O$, 2.05 gm. K_2SO_4, 1.76 gm. KCl, and 1.38 gm. NaCl. Two grams $NaNO_3$ was also added in dissolved portions as the plants developed. This rate of application has been found about 70 percent optimal for these proportions of salts in the growth

of rape under similar cultural conditions. A glass tube 2 cm. in diameter and about 13 cm. long, fixed upright in the soil, provided for aeration and subsurface watering. By daily weighings, the moisture content of the soil was kept at about 50 percent of saturation, as determined by Hilgard's method (29, p. 208, 209), or at about 25 percent on the basis of the weight of the dry soil. Distilled water was used. Eight plants per jar were grown to the first phase of maturity (February 24 to April 19, 1915), as indicated by the death of the basal leaves.

TABLE 3.—*Effects of chlorides introduced into the fertilizer treatment of radish, carrot, and parsnip grown from loam soil in the greenhouse.*

Data.	Complete, K as K_2SO_4.			Complete, K as KCl.			Complete, K as K_2SO_4, plus NaCl		
	No. 1.	No. 2.	Average.	No. 3.	No. 4.	Average.	No. 5.	No. 6.	Average.
Yield of air-dry tops, gm.:									
Radish	8.4	9.1	**8.8**	10.3	9.9	**10.1**	10.2	10.4	**10.3**
Carrot	10.3	9.9	**10.1**	11.7	14.0	**12.9**	11.2	11.5	**11.4**
Parsnip	25.7	23.6	**24.7**	26.3	23.3	**24.8**	21.9	20.5	**21.2**
Yield of oven-dry roots, gm.:									
Radish	9.4	9.3	**9.4**	9.6	9.1	**9.4**	10.4	10.0	**10.2**
Carrot	9.3	11.6	**10.5**	14.1	12.2	**13.2**	13.6	13.6	**13.6**
Parsnip	44.2	38.0	**41.1**	35.0	37.3	**36.2**	25.9	28.7	**27.3**
Dry matter in fresh roots, percent:									
Radish	...	...	**5.8**	...		**5.9**	...	...	**5.4**
Carrot	...	...	**11.8**			**11.6**	...	...	**11.4**
Parsnip	...	...	**23.7**	...		**21.0**	...	...	**21.5**
Sugars in dry roots, percent.									
Glucose:									
Radish	...	...	**16.4**		...	**13.4**	...	...	**13.3**
Carrot	...	...	**17.3**	...	...	**19.6**	...	...	**18.9**
Parsnip	...	...	**5.8**	...	...	**3.7**	...	...	**3.0**
Sucrose:									
Radish	...	...	**4.1**	...	...	**3.7**	...	...	**7.5**
Carrot	...	...	**19.1**	...	...	**19.7**	...	...	**22.5**
Parsnip	...	...	**86.2**	...		**22.6**	...	...	**22.5**

Determinations were made of the sugar contents of the radish roots. In attempting to extract the sugars from the dried, powdered roots of the sugar beet it had been found that the hot alcoholic extraction applied by Stone (61, p. 12) to cereal grains gave incomplete results, even when several times repeated. A modified method was therefore adopted. The dried and powdered roots were first extracted with water, then the aqueous extract was evaporated nearly to dryness and the sugars were removed by subsequent extraction

with alcohol of about 90 percent strength, as diluted by the aqueous residue. After removal of the alcohol and the preparation of the aqueous solution of the sugars the reducing power of the latter, before and after inversion with HCl, was determined, following the Defren-O'Sullivan method (56, p. 74–76). The reducing sugar and invert sugar contents, computed from the reducing power (56, Table 7) probably represent chiefly glucose and sucrose respectively, and they are so designated in the present report.

The results of these tests with radish are given in Table 3, which also presents the corresponding results for carrot and parsnip, to be referred to later. The application of the chlorides seems to have increased the yield of aid-dried leaves of the radish, while only NaCl thus affected the dry matter of the root. The chloride led also to the production of a more watery root. As regards the percentage of sugars in the dry matter of the root, both chlorides somewhat depressed glucose, while NaCl led to an increase of sucrose.

A short-rooted variety of carrot (*Daucus carota*) of unknown name was grown to apparent maturity (May 10 to July 6, 1915, at Madison) in the pots of soil which had produced the radish roots just described, each pot supporting seven plants. The original fertilizer application was repeated, but the moisture of the soil was maintained at only 40 percent of saturation. The data of yields and analyses appear in Table 3.

It is apparent that both chlorides stimulated the production of dry matter in the roots of this plant and, to a less degree, in the tops. The percentage of dry matter in the roots was but slightly reduced by the application of chlorides. While the percentage of glucose was increased by both chlorides, only NaCl enhanced the production of sucrose.

PARSNIP.

In view of the genetic relationship of the parsnip (*Pastinaca sativa*) to the carrot it was considered of interest to test its response to chlorides. The cultures were conducted in boxes of cypress wood, 30 cm. long, 12.5 cm. wide, and 25 cm. deep, conveniently holding 15 kg. of silt loam. Fertilizers were applied as for radish and carrot, but the water supply was not controlled by weighing. A short, round variety of parsnip was employed (January 6 to June 10, 1916, at Madison), three plants in each culture. The data appear in Table 3.

Toxic effects of the chlorides were pronounced with this crop as regards the yield of roots, but the growth of tops suffered only from NaCl. Both chlorides produced more watery roots than did the chlorine-free ration. It appears significant of specific disturbing effects upon metabolism that these more watery roots were decidedly deficient in glucose and seriously depressed in sucrose, as percentages of the dry matter. In these respects the results for parsnip contrast sharply with those for carrot.

SUGAR BEET.

Greenhouse Tests.—The Vilmorin's Improved variety of sugar beet (*Beta vulgaris*) was grown, at the rate of three plants to the culture, in the deep wooden boxes previously described. Series 1 received salts at half the rates specified for the parsnip. In this series NaCl was applied alone, but not supplementary to a complete fertilizer. Series 2 received the fertilizer ration specified for the parsnip. Its growth period extended from January 6 to June 16, 1915, while that of series 1 extended from October 29, 1915, to May 23, 1916, both at Madison. The data for both series appear in Table 4.

TABLE 4.—*Effects of chlorides introduced into the fertilizer treatment of the sugar beet grown upon loam in the greenhouse.*

Description of fertilizer	Culture No.	Yield of air-dry tops.		Yield of oven dry roots		Dry matter in fresh roots		Sugar in dry roots.			
								Glucose.		Sucrose.	
		Ser. 1.	Ser. 2.	Ser. 1.	Ser. 2.	Ser. 1.	Ser. 2.	Ser. 1.	Ser. 2.	Ser. 1.	Ser. 2.
		Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
No fertilizer	1	20.0	..	52.4	.	..	....	.	..	...	....
Do	2	16.5	..	42.3	.	....	..	...	...	.	....
Do.	Average	**18.3**		**47.4**		**18.5**	....	**2.8**	..	**61.3**	...
NaCl only	3	16.9	..	44.7	.	..	..	....	...	...	....
Do.	4	19.9		57.2	...	..	....	....	....	..	....
Do.	Average	**18.4**		**51 0**	...	**17.7**	....	**3.3**	...	**60.3**	....
Complete, K as K_2SO_4	5	27.2	30.5	62.6	34.2	...	..	....	...	....	....
Do.	6	28.7	38.6	47.3	44.1	....	....	..	.	...	.. .
Do.	Average	**28.0**	**34.6**	**55.0**	**39.2**	**16.3**	**25.6**	**2.8**	**2.3**	**60.2**	**77.0**
Complete, K as KCl	7	32.7	43.7	82.4	61.4	....	....	....	..	....	..
Do.	8	38.9	41.3	76.0	56.0	...	....	....	.	..	...
Do.	Average	**35.8**	**42.5**	**79.2**	**58.7**	**16.8**	**23 8**	**4.4**	**2.7**	**57.0**	**74.3**
As 5 and 6, plus NaCl	9	..	46.6	...	61.3	.	.		..	.	.
Do.	10	....	45.7	.	52.3			.	..	.	....
Do.	Average	..	**46.1**	..	**56.8**	.	**24.0**		**3.3**		**60.7**

The data for sugar beet show generally the same departures as those for carrot where chlorides were applied, namely, marked increase in yield of dry matter of roots and smaller increase in yield

of tops, increased percentage of water in the fresh roots, and increased percentage of glucose in the dry roots. The sucrose content, on the other hand, was somewhat depressed by the chlorides, altho the increased production of root more than compensated the slight reductions of sucrose in these roots.

Field Cultures.—The field tests of sugar beet were conducted with the application of common salt alone. The soil was Miami silt loam, previously referred to, which had received liberal applications of farm manure. Rectangular plots of one-eightieth acre (1 × 2 rods) were laid out upon a level area of a field planted to Lane's Improved variety of sugar beet, at Madison. Fine salt was applied broadcast at rates of 260 and 520 pounds per acre upon separate plots either in one application, 12 days after planting, or in two equal applications, 12 and 31 days after planting. The number of plants was reduced to 110 per plot 40 days after planting, this being the least number on any plot at the time. After recording the total weight of the freshly harvested roots, six beets were dried for analysis. The data on yields and composition appear in Table 5.

TABLE 5.—*Effects of adding NaCl to field cultures of sugar beet on loam soil fertilized with farm manure.*

Plot No.	NaCl added	Yield of fresh roots.	Sugars in dry roots.	
			Glucose.	Sucrose
		Kilograms.	*Percent.*	*Percent.*
1	None	90.0	1.7	65.0
2	1,590 gr. (2 applications)	115.0	4.4	61.2
3	795 gr. (do.)	103.6	4.1	71.2
4	1,590 gr. (1 application)	96.7	2.8	54.7
5	795 gr. (do.)	101.3	3.3	53.8
6	None	92.2	2.8	57.2

It will be seen from the data in Table 5 that the number of applications influenced the yield. Thus, although the higher amount of salt produced the least effect when applied as one dressing, it led to the highest yields when distributed between two applications. In a general way, the percentages of glucose increased with the yield of roots, but the percentage of sucrose was depressed by the salt in most cases, and particularly by the single applications. While this limited preliminary test gives little basis for conclusions it appears to justify more extended investigation of the problem involved.

POTATO.

Greenhouse Tests.—Greenhouse cultures of potato (*Solanum tuberosum*) were conducted at Madison in cubical boxes of cypress wood 1 foot deep, containing 20 kg. of Miami silt loam. In the completely fertilized cultures the following kinds and amounts of salts were added per box: $NaNO_3$, 2.44 gm.; $CaHPO_4 \cdot 2H_2O$, 2 gm.; and either K_2SO_4, 3.2 gm., or KCl, 2.74 gm. These amounts of the potassium salts are chemically equivalent. In some cultures KCl replaced one-fourth, one-half, or three-fourths of the K_2SO_4 of the complete ration, and in other cases K_2SO_4 and KCl were applied alone at the maximum rate of the complete ration. NaCl was similarly employed, as is indicated in Table 6. One of each pair of duplicate cultures, of the Triumph variety, received 8 gm. of $CaCO_3$. As already intimated, the rations were so manipulated that the various applications of potassium salts supplied the same amount of potassium, and the same was true of the chlorine supplied by the chlorides.

One plant per culture was grown from a cubical cutting about 2.5 cm. thick. Distilled water was supplied as the appearance of the soil indicated need, and each series was harvested as soon as all the tops appeared mature. All tubers less than half an inch in diameter were discarded and the remainder were sliced and dried at 55° C. Starch determinations were then made by the standard method of the American agricultural chemists (78, p. 53.)[5] Filtered saliva was employed as the hydrolizing agent, and the glucose finally produced was determined in the manner already described. No correction was made for the small amount of reducing sugars probably present in the tubers.

In Table 6 the average data for duplicate cultures are given thruout, as liming was found to produce no specific effects upon either yield or composition of the tubers. In series 1, the Triumph variety was grown, and tubers from this series were employed as seed for series 2. Series 3 was grown in a sandy soil from Spooner, Wis., but in all other cases Miami silt loam was employed. Series 4 was conducted with the Rural New Yorker variety.

While the limited data of Table 6 do not justify conclusive statements they indicate superiority of KCl over K_2SO_4 in the complete fertilizer, relative to percentage and total yield of dry matter in the tubers. As regards percentage of starch the Triumph variety was in-

[5] Comparative trials had shown the measurement of starch by specific gravity of the tubers to be unreliable. This result is confirmed by Watson (Va. Agr. Expt. Sta. Bul. 55, 1905) and by Morrison (unpublished thesis for degree of B.Sc., Univ. of Wis., 1911.)

different to KCl, while the Rural New Yorker was depressed thereby, in the completely fertilized cultures. Judged by all three of the criteria employed, both potassium salts were detrimental when applied alone to the late variety of potato, but KCl the more so, as compared with the unfertilized cultures. It does not appear that NaCl was particularly injurious to the Triumph variety, excepting the production of more watery tubers, as compared with the unfertilized controls. In the latter respect, however, its results fall short of those of the complete fertilizer. Evidently the variety of potato is a more determinate factor than the type of soil in the effects of chlorides observed under these conditions.

TABLE 6.—*Effects of chlorides upon the yield and composition of potato tubers grown in soil cultures in the greenhouse.*

Data.	No fertilizer.	Complete.					K_2SO_4 only.	KCl only.	NaCl only.
		All potassium as K_2SO_4.	0.75 of potassium as K_2SO_4, 0.25 as KCl.	0.50 of potassium as K_2SO_4, 0.50 as KCl	0.25 of potassium as K_2SO_4, 0.75 as KCl.	All potassium as KCl.			
Number of tubers per culture.									
Series 1	2	3	3	3	4	3	....	.	2
Series 2	6	5	1	6	3	7	....	...	2
Series 3	1	3	...	.	...	3	.	.	1
Series 4	3	4	4	4	3	4	4	2	...
Yield of air-dry tubers, gm.:									
Series 1	5.7	9.0	9.9	11.8	16.9	16.5	..	..	7.1
Series 2[a]	27.4	71.8	1.2	71.8	36.0	91.0	.....	....	6.1
Series 3	7.5	8.1	......	..	.....	6.6	...	..	7.3
Series 4	11.9	11.7	9.8	8.9	8.6	13.2	9.9	5.9	...
Air-dry matter in fresh tubers, percent:									
Series 1	24.2	21.8	20.4	21.3	22.1	23.7	......	......	23.2
Series 3	25.5	15.9	.....	.....	.....	17.2	.....	.....	19.1
Series 4	24.6	20.7	18.1	22.1	21.1	22.8	20.9	18.8	....
Starch in dry matter, percent:									
Series 1	80.0	74.0	......	..	...	75.3	.....	......	78.5
Series 3	75.3	75.8	.....	...	...	78.3	......	......	75.3
Series 4	77.4	78.6	77.7	72.6	71.3	70.5	73.2	71.7	......

[a] The data for this series are for fresh tubers instead of air-dry ones.

Field Cultures.—Field tests of chlorides upon the potato were conducted at Madison, with a basal fertilizer ration per acre of 160 pounds of $NaNO_3$, 400 pounds of acid phosphate, and 200 pounds of K_2SO_4. KCl was substituted for K_2SO_4 by intervals of one-fourth of the full amount of potassium, as in the greenhouse cultures. In addition to an unfertilized plot, NaCl was applied alone at the rate of 136 pounds

per acre, equivalent to the maximum application of KCl in the complete fertilizer. The plots were of the shape and size employed for the sugar beet, but they were laid out permanently with alleys 3 feet in width between adjacent plots. $NaNO_3$ was broadcasted over the plots in two applications as the plants developed, but the other fertilizers were applied with the drill. Series 1, Triumph variety, matured in 111 days, with a severe drouth from the 38th to the 108th day. Series 2, Rural New Yorker variety, matured in 127 days, but a prolonged period of heavy rains near the close of this period caused excessive loss of the tubers by decay. The crop of series 1 was divided into marketable and unmarketable tubers, the former weighing 65 gm. or more each. Six tubers of average size were selected from this lot for analysis. Only the two marginal and two middle rows of each plot were dug in series 2. Twelve representative tubers were then taken for cooking tests[6] and for analysis. All of the data here referred to are presented in Table 7.

TABLE 7.—*Effects of chlorides upon the yield and composition of potato tubers grown on field plots.*

Description of fertilizer.	Marketable tubers, series 1.	Yield of air-dry tubers, series 1	Dry matter in fresh tubers.		Starch in dry matter.		Relative score of cooking quality.	
			Ser. 1	Ser. 2	Ser. 1	Ser. 2.	Boiling	Baking
	Pct.	*Grams.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*		
No fertilizer.	45	3,270	19.2	20.7	[a]71.8	[b]80.1	5	6
Complete, all potassium as K_2SO_4.	49	4,310	18.4	20.6	72.3	81.0	3	2
Complete, 0.75 of potassium as K_2SO_4, 0.25 as KCl. . .	39	4,470	20.4	20.4	. .	.	2	3
Complete, 0.5 of potassium as K_2SO_4, 0.5 as KCl. . . .	44	4,270	18.6	19.7	. . .		4	4
Complete, 0.25 of potassium as K_2SO_4, 0.75 as KCl. . .	48	4,150	18.1	20.4	. . .	. . . .	6	5
Complete, all potassium as KCl .	53	4,120	18.5	21.0	73.4	79.9	1	1
NaCl only . . .	35	2,650	18.1	20.0	71.4	79.7	7	7

[a] Mother tubers contained 72.4 percent of starch.
[b] Mother tubers contained 75.7 percent of starch.

In series 1 (Triumph variety) the higher amounts of KCl in the complete fertilizer appear to have depressed the yield of dry matter, while NaCl exerted this effect decidedly, as compared with the unfertilized plot. The only significant departure from a uniform percentage of marketable tubers seems to have been the decline due to

[6] Performed by Miss Ada Hunt, of the Home Economics Department of the University of Wisconsin.

NaCl. While KCl was without effect upon the percentage of dry matter in the tubers of either series, NaCl alone seems to have slightly decreased this value. No significant variations in the percentage of starch resulted from the varied fertilizer treatment. In cooking quality the tubers produced by the fertilizers containing the greater proportions of K_2SO_4 were generally superior to those receiving more KCl, but those receiving potassium entirely as KCl scored first by both tests. There was no doubt of inferiority of the tubers produced with NaCl alone, these being particularly characterized by the judges as "of a bitter, alkaline flavor."

While these results indicate that chlorides influence the yield of the potato tuber much more than they affect its composition, their chief value appears to lie in the results they promise for more extended investigation along the lines indicated here.

Succeeding field crops have apparently benefited from the chlorides applied to the potato crops just described. Following the Rural New Yorker potatoes, the plots were sown to barley (*Hordeum vulgare*) and common red clover (*Trifolium pratense*). In the following year (1916), the yield of barley grain on the unfertilized plot was 10.5 pounds, while on the plots which had been completely fertilized for the potatoes it ranged from 12.5 to 16.0 pounds, and where NaCl had been applied alone it amounted to 15.0 pounds. The ratios of grain to straw for these respective treatments were 0.45, 0.45 to 0.52, and 0.56, respectively. The yield of grain and the ratio of grain to straw increased with the proportion of KCl in the rations of the completely fertilized plots. In the following year (1917), the yields of clover hay were 45 pounds for the unfertilized plot, 56 to 60 pounds for the completely fertilized plots, and 63 pounds for the plot which had received NaCl only. The yields were practically the same whether K_2SO_4 or KCl had been applied in the complete fertilizer.

The Mechanism of Chlorine Effects.

NATURAL SUPPLY.

In considering the possible use of chlorides as fertilizers it is important to take account of the supply of chlorine in the soil. There is also some acquisition of this element in the rainfall, although a portion of this supply doubtless circulates within local areas of soil and atmosphere.

The following chlorine-bearing minerals, soluble in water or dilute acids, appear to occur commonly in soils (3, p. 182; 50, p. 48), namely: Halite (NaCl), sylvite (KCl), apatite [$Ca_4.Ca.Cl.F(PO_4)_3$], and

sodalite [$Na_4(AlCl)Al_2(SiO_4)_3$]. Few, if any, soil analyses give data on the total chlorine content of the soils concerned. Preliminary attempts to secure such data in the present study by the method of alkaline fusion (30, p. 184) encountered difficulties, but a number of determinations of water-soluble chlorine were made upon air-dried samples of soils pulverized to pass a sieve having 100 meshes to the inch. Extracts of 25 grams of soil in 400 cc. of water, obtained by agitation for two hours at 17° C., were filtered as clear as possible through double filter papers (Schleicher and Schull paper No. 595) and washed to a volume of 500 c.c. Chlorine was determined in 200 c.c. aliquots of the solution, in the manner recommended by Hillebrand (30, p. 183). The results appear in Table 8.

TABLE 8.—*Content of water-soluble chlorine in air-dried Wisconsin soils.*

Type of soil.	Chlorine, percent in air-dry soil.	Chlorine, pounds per acre foot.[a]
Miami loam	0.005	150
Lancaster loam	0.009	270
Superior Clay	0.008	240
Spooner sand	0.005	175
Peat (University marsh)	0.019	380

[a] The following values were ascribed per acre-foot of air-dry soil: Peat, 2,000,000 pounds; loam and clay, 3,000,000 pounds; and sand, 3,500,000 pounds.

From the data given by Hopkins (32, Tables 23, 131b) the annual removal of chlorine per acre by common crops may be calculated to range approximately from 5 pounds in cereal grains (seed only) to 50 pounds for the sugar beet (root only). Tobacco ranks high as a chlorine-absorbing plant, the leaves and stems accumulating 125 pounds of the element per acre, in some cases. Hays and straws account for the annual removal of about 30 pounds of the element per acre. These considerations indicate the inadequacy of the soil supply of chlorine for maintaining the usual plant content of the element in cropping systems.

Leaching is apparently a more serious factor than cropping in the annual depletion of soil chlorides, but both are partly compensated by the chlorine compounds washed to the soil in rain. At the Rothamsted Experiment Station, Lawes, Gilbert, and Warington (40, p. 263–266, 346, 347) found the loss of chlorine in subsurface drainage waters to be approximately equal to the supply from rain, fluctuating with the latter. As remarked by these authors, the chlorine content of rain usually decreases with the distance from the ocean. The annual supply per acre at Rothamsted was found to be 13.4 pounds, the

content per unit of precipitation being about 2.5 times as great in winter as in summer. Vituynii (67) reports average annual precipitations per acre of from 7.4 to 20.5 pounds of chlorine at eight Russian stations; and Knox (38) found a corresponding fall of nearly 37 pounds at Mt. Vernon, Iowa, during only eight months, from summer to spring. The latter unusual observation may be explained by supposing that chlorides had been transported by wind from the arid regions farther west.

In the present investigation 30 inches of rainfall for the period from July to September, inclusive, 1915, contained 5.9 pounds of chlorine per acre, while 43 inches of precipitation for the period from July to October, inclusive, 1917, contained 6.3 pounds of chlorine. From November to January, inclusive, 1917–18, 36 inches of snowfall (equivalent to 3.5 inches of rain) contained 1.7 pounds of chlorine. At these rates the total annual atmospheric supply of chlorine per acre at Madison is approximately 16 pounds, equivalent to 26 pounds of NaCl. This value probably exceeds the average, for the partial rainfall examined in 1915 was equal to the normal annual precipitation for this region. For the periods here observed the chlorine supply per acre-inch of precipitation in equivalents of rain is about 0.2 pound for rain and 0.5 pound for snow, which agrees with the findings at Rothamsted. The higher chlorine supply of the winter months may be due to an inclusion of wider areas by storms in the drier atmosphere of these months, as compared with summer, more distant sources of the element thus being brought into play. Increased combustion of fuel might also enhance the atmospheric supply of chlorine in winter.

From the foregoing consideration it appears that the chlorine content of soils in humid regions tends toward a minimum, the magnitude of which is largely determined by the chlorine content of the rainwater and the nature of the crops removed. If a certain chloride content of the soil is essential for the best production of some crops it is quite possible, and even probable, that the value of this minimum may be too low. Under these conditions the use of common salt in conjunction with the usual fertilizers should become a practical consideration, as indicated by some of the results considered above.

EFFECTS OF CHLORIDES UPON THE SOIL.

It has been contended by various authorities that sodium chloride may favor plant growth by liberating potassium. The results of Schulze (54) seem to indicate quite conclusively, however, that this effect is not universally important. To one portion of a sand-loam

mixture he added a potassium-containing zeolite, to another portion the zeolite was applied with sodium chloride, and a control portion was left untreated. Both treated soils gave greater yields of white mustard than did the control. The yield where NaCl was applied was about twice as great as where the zeolite was used alone, but the potassium content of the plants was the same from the two fertilizer treatments. From these results Schulze concluded that sodium served directly as a plant nutrient.

Experiments with oats led Soderbaum (60) to believe that NaCl acted directly upon the plant by virtue of its chlorine content. He employed three portions of a soil deficient in chlorine, to each of which was added a complete fertilizer containing one of the following salts as a course of nitrogen, namely, $NaNO_3$, $(NH_4)_2SO_4$, and NH_4Cl. Sodium chloride, equivalent in amount to the $NaNO_3$ used, was added to similarly fertilized portions of the soil. The total yield was increased by NaCl, when this was added with the first two sources of nitrogen, but not when it was added with NH_4Cl. Hence the benefit derived from NaCl was thought to be specifically due to its chlorine content.

There remains the possibility of indirect action of chlorides upon plant growth, as by influencing the soil flora in such manner as to alter the fertility of the soil. In this connection it may be mentioned that C. B. Lipman (41) found NaCl toxic to ammonifying bacteria, but stimulating to nitrifying and nitrogen-fixing organisms, at rates of application from 0.05 to 0.5 percent, on the basis of dry weight, in a sandy soil. Greaves (20) observed stimulation of ammonification in a sandy soil by NaCl at a concentration of about 0.01 percent, although the salt was toxic at twice that concentration. Greaves' smaller application is equivalent to about 350 pounds of salt per acre-foot of soil, an amount found favorable in the fertilizing tests already described. Other chlorides differed widely from NaCl in their effects on ammonification, as noted by Greaves. He states that the same concentration of sodium chloride is required to reduce ammonification and the yield of wheat in the field, each to half the normal value. It seems, from the preceding citations, that chlorides may affect the growth of higher plants by altering the biological production of available nitrogen compounds in the soil. Nevertheless, from the known limited influence of fertilizers upon the composition of plants and in view of the variable response of different plant species to the application of chlorides under similar conditions, this supposition seems quite inadequate to explain the changes of plant composition produced by these salts.

POSSIBLE MECHANISM OF CHLORINE EFFECTS WITHIN THE PLANT.

Nothing is known as to how NaCl and other chlorides may bring about such physiological responses in plants as are here mentioned. Many physiological responses to the presence of inorganic salts have been regarded by Loeb (44, p. 78–95) and others as due to changes in ion-protein compounds within the living protoplasm. In his theory of ion-protein compounds Loeb postulates the formation and disruption of such compounds by enzyme action. Livingston (42, p. 22, 23) has advanced a somewhat similar hypothesis to account for the toxicity and stimulating influence of certain metals to plants. If chlorine is involved in organic compounds of the plant these must be very unstable. Evidence to this end is furnished by the work of Schmidt (53), who found the entire chlorine content of sugar beet seed to be soluble in water and capable of direct precipitation by $AgNO_3$. This may be regarded as strong evidence of the absence of any considerable amounts of organic chlorine compounds in this seed. It therefore appears probable that the chlorine of the sugar beet, and perhaps of other plants, exists in the cells largely as inorganic chlorides, comparable to those absorbed from the soil.

The apparent relation of chlorine content to accumulation of starch in the potato tuber (Pfeiffer *et al.*, 49) suggests enzyme activity as a main controlling condition for this effect. That chlorides which may readily exist in plant cells greatly accelerate the action of ptyalin of the human saliva is clear from the work of Wohlgemuth (77). Cole (14) obtained similar results with ptyalin, but found that the action of invertin was considerably retarded by NaCl. Stimulation of diastatic enzymes from plant sources by the action of chlorides has been observed by Kellerman (36) and by Hawkins (28).

If, supported by the foregoing evidence, we suppose that the concentration of chlorides in the cell may exert marked controlling influence upon the activities of intracellular enzymes, especially the diastatic ones, and if we suppose that many vital activities of the plant are controlled in their turn by enzyme action, we arrive at a general suggestion of a possible way by which variations in the concentration of these salts may bring about such physiological responses as have been observed. This hypothesis is, of course, very general in its nature and only tentative, but it may serve to connect the various facts as we know them at present. As more information accumulates this suggestion may be elaborated, modified, or discarded, as may be determined.

SUMMARY.

A survey of previous field and greenhouse investigations of the effects of chlorides upon the growth and composition of plants discloses extremely variable results. It is apparent that the species of plant, the type of soil, and especially the complex of factors considered as climate, greatly influence these effects.

In the present investigation the introduction of potassium and sodium chlorides into water cultures but slightly affected wheat plants during the first five weeks after germination. Buckwheat grown to apparent maturity in similar cultures was decidedly affected by the application of these chlorides. Although seed production remained apparently undisturbed, the length of roots and the yield of dry matter was depressed. The least production of dry matter in leaf blades and the greatest depression of water absorption per unit of dry matter of the foliar tissue occurred in the presence of sodium chloride.

The radish responded only slightly, in yield and composition, to the application of potassium and sodium chlorides along with complete fertilizer in soil cultures in the greenhouse. Under similar conditions, increased production of dry matter and of the percentages of sugars therein resulted with the carrot, while the reverse was true of the parsnip. In the latter case sodium chloride was particularly injurious.

The sugar beet gave the same general responses to chlorides as did the carrot, when grown in the greenhouse. While the roots were more watery where chlorides were applied, the yield of dry matter was greatly increased. The dry matter of such roots contained more glucose, but less sucrose, than that obtained from cultures in soil not receiving chlorides. Similar responses followed the application of common salt alone to beets grown in the field.

The potato produced increased yields of dry matter in the tuber when potassium chloride was supplied in place of potassium sulfate, in a complete fertilizer ration, to soil cultures in the greenhouse. Relative to the percentage of starch, the Rural New Yorker and Triumph varieties of potato responded differently, the former being depressed while the latter was unaffected. The results indicated that the variety of plant was more important than the type of soil in determining this effect of chlorides. In field cultures in a dry season the application of potassium chloride in a complete fertilizer decreased the yield of dry matter in the tubers, but not the percentage of marketable tubers, of the Triumph variety. In a season which was very humid toward its close, no significant differences in composition

or cooking quality were found between tubers of the Rural New Yorker variety produced where potassium sulfate and potassium chloride were employed separately in a complete fertilizer ration. Sodium chloride applied alone altered the composition of the tubers only slightly in this test, but affected their quality seriously.

Determinations of the water-soluble chlorides in several types of Wisconsin soils have shown them to be equivalent to about 150 to 380 pounds of chlorine per acre-foot. It is shown that this supply is inadequate for long maintaining the usual plant content of the element in crop rotations. The annual supply of chlorine in rain and snow at Madison is about 16 pounds per acre, but, judging from conditions at the Rothamsted Experiment Station, this acquisition is probably counterbalanced by losses in drainage waters.

Evidence is cited which indicates that sodium chloride serves directly as a fertilizer, and that chlorine is the active element therein. Further evidence indicates a possible rôle of chlorides in stimulating the biological production of available nitrogen compounds in the soil, but this effect seems inadequate for explaining all of the varied responses of higher plants to the application of chlorides.

Proceeding from the observed effects of chlorides upon diastase and other enzymes which act upon carbohydrates, a tentative hypothesis is advanced to explain the varied physiological responses of plants to chlorides through regulation of enzyme activity by these salts.

On the whole, it appears quite possible that further investigation may lead to the development of practical rules for the use of chlorides in agriculture in such ways as to increase and improve certain crops, due account being taken of those crops injured by these salts, as well as of climatic and soil conditions.

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FIELD TECHNIC IN DETERMINING YIELDS OF PLOTS OF GRAIN BY THE ROD-ROW METHOD.[1]

A. C. ARNY AND R. J. GARBER.

INTRODUCTION.

Determining the yields of grain on varietal, rotation or soil fertility plots or on large fields by harvesting portions of the areas is frequently desirable or necessary. The necessity may arise at outlying fields where tests are made in cooperation with farmers or at substations where facilities are lacking for harvesting or thrashing accurately the product of the entire areas. Also, it is frequently desirable to harvest portions of plots as a check on the yields obtained from harvesting the entire areas.

The value of any method used for this purpose depends upon (*a*) the degree of precision which may be obtained from its use, (*b*) the labor required, and (*c*) ease of manipulation. In the present paper, data are given (*a*) on the precision obtained by determining yields by the removal of rod rows from tenth-acre plots as compared with harvesting and thrashing the entire plots, and (*b*) the comparative labor requirements of determining yields by the two methods.

REVIEW OF LITERATURE.

McCall (3)[2] gives directions for making an apparatus to be used in measuring off areas of 1/5,000 acre in grain or grass plots. An outline of a plot is given showing the location of five areas, making a total of 1/1,000 of an acre, which were removed from each plot of wheat and timothy in a preliminary trial. The statement is made that the results secured by this method checked quite satisfactorily with the yields ascertained by harvesting and thrashing the product of the entire plots. The inclusion of border rows in each area harvested is a serious objection to the use of the method as outlined, especially in varietal test plots. Removal of at least two border rows from either side of each plot before taking the samples would tend to remove this objectionable feature.

Arny and Hayes (1) show that increase in yield due to the utilization of alley space by the two border rows on the sides only of plots

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[2] Reference is to "Literature cited," p 47.

8.25 feet wide and 132 feet long varied from 7.48 to 15.78 percent, with an average of 12.78 percent, for 11 varieties of oats. For 5 varieties of wheat, the increase in yield from this cause varied from 14.07 to 23.51 percent, with an average of 18.41 percent. For 4 varieties of barley the increase in yield ranged from 14.28 percent to 24.13 percent, with an average of 20.64 percent. The grain was drilled in 6-inch rows. The results indicate that alley effect extends over an area at least 1 foot in width within the margins of plots and that some varieties utilize alley space more efficiently than others. Therefore, the inclusion of border rows, particularly in varietal plots surrounded by alleys, may introduce a source of error sufficiently great to offset any superiority in ability to yield which one variety may have over another.

Hayes and Arny (2) present data which indicate that three or four systematically replicated rod rows spaced 1 foot apart, sown at the regular field rate, when the possible effect of competition between varieties is overcome by border rows, are about as accurate as any number below nine.

Material and Methods.

The Soils Division has in progress at University Farm and at the several substations fertilizer experiments conducted on a uniform plan. The treatments in addition to the check are designated as treatments A, B, C, D, and E. Each treatment is repeated three times. The plots are 2 rods wide by 8 rods long, or approximately one-tenth acre in size. The drill rows are 6 inches apart. On each series devoted to this work, lime is applied crosswise to half of each plot. On account of the difficulty of dividing accurately the grain on the limed and unlimed halves, these yields in 1917 were determined by removing and thrashing separately four definitely spaced rod rows of the grain from each half plot. The yields of the limed and unlimed portions, as determined by this method, will be published by the Soils Division. The results from the eight rod rows used in determining the yields of the limed and unlimed portions, together with the results from a ninth row removed at the same time from approximately the center of each plot, have been combined in various ways and compared with the yields ascertained by harvesting the entire plots.

The location of each rod row within a plot is shown in figure 1. At the Morris substation, the drill rows ran crosswise of the plots and the plan was modified to meet the conditions.

A piece of straight-grained oak 1 rod in length and three-quarters by a half inch in thickness was used in measuring off the rod rows. A measure of this kind was found very convenient, but any other sort of a rod stick would have served the purpose. In the removal of the rod rows of grain in any one experiment the worker always started in the same corner of the plot. Assuming that he started at the northeast corner, he first counted south to the fifth drill row and stepped into the plot 5 feet or two short paces. Rod row No. 1 was then laid off and the grain was pulled or cut, bound, and tagged. The worker then walked south to the twenty-fifth drill row and west 10 feet or three paces, removed rod row No. 2, and continued the round, harvesting the rod rows in numerical order. The nine small

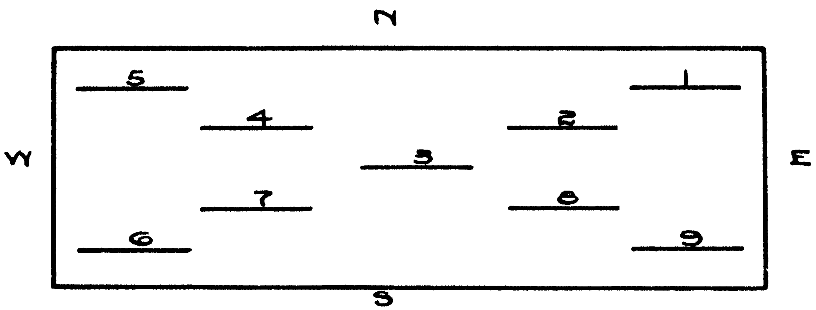

FIG. 1. Outline of plot showing the location of the rod rows. Row 1 is the 5th row, 2 feet from the end; Row 2, 15th row, 24.5 feet from end; Row 3, 34th or 35th row midway from ends; Row 4, 16th row, 24.5 feet from end; Row 5, 6th row, 2 feet from end; Row 6, 6th row, 2 feet from end; Row 7, 16th row, 24.5 feet from end; Row 8, 15th row, 24.5 feet from end; Row 9, 5th row, 2 feet from end.

bundles were then carried out and the heads or panicles removed by laying the bundles over the edge of a box and using a hookshaped cornknife with serrated blade to cut the straw. The heads or panicles of each rod were then placed in a flour bag and hung up under the eaves of a building to dry. At the substations, the flour bags containing the unthrashed grain were placed in large jute bags and shipped to University Farm. After being thoroly dried, the grain in each bag was beaten out by hand and separated from the straw and chaff by running thru a fanning mill. In this trial, in order that the different combinations could be made for comparison with the yield secured from harvesting the entire tenth-acre plot, the yield of grain from each rod row was necessarily determined separately. In the actual use of this method in ascertaining yields, the rod rows harvested from each plot need not be kept separate.

The combinations of the yields of rod rows for comparison with the yields ascertained by harvesting the entire tenth-acre plots including what was removed in the rod rows, were made as follows. For the determination by 4 rows, the yields of row numbers 2, 4, 7, and 8 were averaged; for the determination by 5 rows, the yields of row numbers 1, 3, 5, 6, and 9 were averaged; and for the determination by 9 rows, the yields of all the rows removed from each plot were averaged. The yields from the three plots as determined by harvesting the entire tenth acre, 9, 5, and 4 rod rows are averaged to obtain the yield for the check and for each treatment.

In making direct comparisons of the value of the several treatments indicated by the yields as determined from harvesting the entire plots and from the rod rows removed from the plots, the least percentage difference which is taken as significant was derived by the pairing method employed by Wood and Stratton (4).

In deriving the probable errors used in discussing the results from the tenth-acre plots and from the rod rows, the yields of each consecutive pair of plots receiving the same treatment were averaged and the deviation from the mean of each pair ascertained. Each deviation was then calculated to a percentage of the mean yield of the pair. The different steps in deriving the deviation in percentage of the mean of each pair are made clear by using the yields per acre of the three check plots of oats numbered 1, 7, and 13 in the test at University Farm, which are 77.8, 73.3, and 80.7 bushels respectively, as shown in Table 1.

TABLE 1.—*Yields of plots of oats similarly treated, with percentage deviations of mean of each pair.*

Plot numbers.	Average yield in bushels per acre of pairs of similarly treated plots.	Deviations in bushels per acre from the mean yields of the pairs.	Deviation in percentage of mean of each pair.	Deviation in percentage of each pair squared.
1 and 7	75.6	2.3	3.04	9.24
7 and 13	77.0	3.7	4.81	23.14

After the deviation in percentage of the mean of each pair had been ascertained, the arithmetical mean of the total number of percentage deviations was calculated. This gave the probable error for a single determination in percentage of the mean. The results for the 168 pairs of tenth-acre plots and the 432 pairs of rod rows were plotted in frequency curves, which are shown in figure 2.

The probable errors in percentage of the mean yields from the tenth-acre plots vary from 3.56 percent for the oats at Morris to 10.10 percent for the oats at Duluth. Where the results from all the plots are considered, the probable error in percentage of the mean is 5.35. The mean probable errors for the tenth-acre plots and rod rows of oats and wheat at the various stations are shown in Table 2.

TABLE 2.—*Mean probable errors for yields of the tenth-acre plots and the rod rows in percent of mean yield of each pair and in percent of mean yield of each pair squared.*

Crop and location.	No. of pairs	Probable errors in percent of mean	Probable errors in percent of mean squared
Tenth-acre plots:			
Oats at Duluth	12	10.10	14.74
Oats at Morris	36	3.56	4.79
Oats at University Farm	48	4.87	5.47
All oats	96	5.03	7.22
Wheat at Morris	36	5.06	9.36
Wheat at University Farm	36	6.50	9.52
All wheat	72	5.78	7.00
All oats and wheat	168	5.35	7.12
Rod rows:			
Oats at Duluth	108	13.69	16.83
Oats at University Farm	108	9.12	11.59
Wheat at University Farm	108	9.69	12.29
Wheat at Morris	108	7.75	9.95
All oats and wheat	432	9.98	12.93

For the rod rows the mean probable errors vary from 7.75 percent for the wheat at Morris to 13.39 percent for the oats at Duluth. When the total number of rows is included, the mean probable error is 9.98 percent. The probable error for the tenth-acre plots, 5.35 percent, is practically identical with that given by Wood and Stratton (4) for plots above $\frac{1}{80}$-acre in size. For the rod rows, which are $\frac{1}{5280}$-acre in size, the probable error is somewhat lower than that given by Wood and Stratton.

Work with a large number of similarly treated plots in other experiments indicates that squaring the deviation in percent of the mean for each pair before calculating the arithmetical mean and afterwards extracting the square root gives a probable error more nearly approaching that ascertained by expressing in percentage of the mean the probable error for a single determination derived in the ordinary way. Inspection of the probable errors ascertained by the squaring method as compared with those not squared, as given in Table 2, shows the former to be higher in each instance.

For the reason that the probable errors derived by the squaring method more nearly approach those derived by the ordinary method and that they are higher and hence more conservative, they are used in the following discussion.

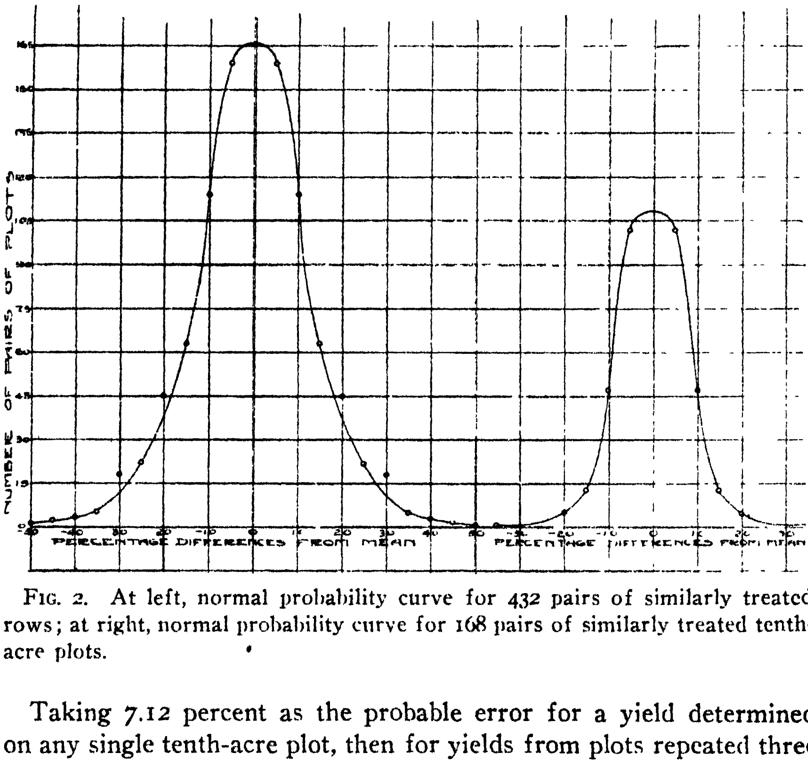

FIG. 2. At left, normal probability curve for 432 pairs of similarly treated rows; at right, normal probability curve for 168 pairs of similarly treated tenth-acre plots.

Taking 7.12 percent as the probable error for a yield determined on any single tenth-acre plot, then for yields from plots repeated three times the error would be $\frac{7.12}{\sqrt{3}}$ or 4.12 percent. For the rod rows the probable error of a single determination was found to be 12.93 percent and hence, for the mean of one rod row in each of three repeated plots the error is $\frac{12.93}{\sqrt{3}}$ or 7.47 percent. For rod rows repeated nine, five, and four times in each of three similarly treated tenth-acre plots, the probable errors are $\frac{7.47}{\sqrt{9}}$ or 2.49 percent, $\frac{7.47}{\sqrt{5}}$ or 3.34 percent, and $\frac{7.47}{\sqrt{4}}$ or 3.79 percent, respectively.

The odds are 30:1 against a deviation of 3.81 times its probable error in one direction only being due to normal variation (4).

Multiplying the errors in percent, 4.12, 2.49, 3.34, and 3.79, by 3.81, the least significant difference between any two treatments is found to be 15.70 for three similarly treated tenth-acre plots, and 9.49, 12.73, and 14.44 respectively for 9, 5, and 4 rod rows removed from triplicate tenth-acre plots.

As the probable errors in percentage of the means squared, for both the tenth-acre plots and for the rod rows, are radically greater at Duluth than at the other locations, it seems necessary to use these in the interpretation of the results at this location instead of the probable errors derived from considering the yields of all the plots or rows. The probable errors for the yields for a single determination of the oats at Duluth derived by the squaring method are 14.74 percent for the tenth-acre plots and 16.83 percent for the rod rows respectively. For three tenth-acre plots of the same treatment, the error is $\frac{14.74}{\sqrt{3}}$ or 8.51 percent, and for a rod row removed from each of three similarly treated tenth-acre plots, the error is $\frac{16.83}{\sqrt{3}}$ or 9.72 percent. For rod rows repeated 9, 5, and 4 times in each of three similarly treated tenth-acre plots, the errors are $\frac{9.72}{\sqrt{9}}$ or 3.24 percent, $\frac{9.72}{\sqrt{5}}$ or 4.35 percent, and $\frac{9.72}{\sqrt{4}}$ or 4.86 percent, respectively.

Multiplying the errors in percentage for the work at Duluth, 8.51, 3.24, 4.35, and 4.86, by 3.81, the least significant difference in percent between any two treatments is 32.4 for three similarly treated tenth-acre plots; and 12.34, 16.56, and 18.51 respectively for 9, 5, and 4 rod rows removed from triplicated plots similarly treated.

The probable error of the difference between two statistical constants was determined by taking the square root of the sums of the squares of the probable errors of the two constants.

Relative Precision of Yields from Tenth-Acre Plots and from Rod Rows Removed from Them.

For each location, the yields ascertained by the four methods for the three plots of each treatment, together with the mean yield, the standard deviation, and coefficient of variability are tabulated. The percentage increases for each treatment are also given.

RESULTS WITH WHEAT AT THE MORRIS SUBSTATION.

Examination of the mean yields in Table 3 for the check and the various fertilizer treatments show a close agreement for the determinations by the different methods.

TABLE 3.—*Comparison of yields and variability of Marquis wheat grown at the Morris substation under six different treatments as determined from triplicate tenth-acre plots and from 9, 5, and 4 rod rows removed from tenth-acre plots.*

Fertilizer treatment.	Source	Yields in bushels per acre for each of the triplicate plots.			Means	Standard deviations.	Coefficients of variability.
Check	Tenth-acre plots..	28.10	29.50	26.62	28.07 ±0.46	1.17 ±0.32	4.17 ±1.15
	Nine rod rows. ..	25.97	29.96	26.86	27.60 ±0.67	1.71 ±0.47	6.20 ±1.71
	Five rod rows.. .	24.42	32.50	25.10	27.34 ±1.43	3.66 ±1.01	13.44 ±3.76
	Four rod rows ..	27.96	26.86	29.13	27.98 ±0.36	0.93 ±0.26	3.32 ±0.91
A	Tenth-acre plots..	29.16	32.53	30.63	30.77 ±0.54	1.38 ±0.38	4.48 ±1.23
	Nine rod rows. .	29.29	31.67	27.85	29.60 ±0.62	1.58 ±0.44	5.34 ±1.46
	Five rod rows...	28.74	30.61	28.98	29.48 ±0.32	0.63 ±0.23	2.82 ±0.78
	Four rod rows. .	30.05	33.07	26.50	29.87 ±1.05	2.69 ±0.74	9.01 ±2.48
B	Tenth-acre plots	34.04	33.49	32.70	33.41 ±0.21	0.55 ±0.15	1.65 ±0.45
	Nine rod rows....	32.42	29.30	32.09	31.27 ±0.55	1.40 ±0.29	4.48 ±1.23
	Five rod rows. ..	32.22	28.56	34.59	31.79 ±0.97	2.48 ±0.68	7.80 ±2.15
	Four rod rows....	32.74	30.30	29.05	30.70 ±0.60	1.53 ±0.42	4.98 ±1.37
C	Tenth-acre plots .	29.32	33.87	32.53	31.91 ±0.74	1.91 ±0.53	5.99 ±1.65
	Nine rod rows. .	31.16	31.76	31.66	31.53 ±0.10	0.26 ±0.07	0.82 ±0.23
	Five rod rows....	30.71	30.14	33.36	31.74 ±0.51	1.31 ±0.36	4.13 ±1.14
	Four rod rows....	30.52	33.85	29.61	31.33 ±0.71	1.82 ±0.50	5.81 ±1.60
D	Tenth-acre plots..	36.46	37.56	35.20	36.41 ±0.37	0.96 ±0.26	2.64 ±0.73
	Nine rod rows....	37.68	33.36	31.76	34.27 ±0.97	2.50 ±0.69	7.30 ±2.10
	Five rod rows....	35.78	33.12	31.52	33.47 ±0.69	1.76 ±0.48	5.26 ±1.45
	Four rod rows....	40.11	32.74	32.14	35.33 ±1.34	3.44 ±0.95	9.74 ±2.68
E	Tenth-acre plots..	34.76	33.59	35.75	34.70 ±0.34	0.88 ±0.24	2.54 ±0.70
	Nine rod rows....	35.20	35.27	34.55	35.01 ±0.12	0.32 ±0.09	0.91 ±0.25
	Five rod rows...	36.26	35.90	37.55	36.57 ±0.28	0.71 ±0.20	1.94 ±0.53
	Four rod rows....	33.96	34.57	30.81	33.11 ±0.64	1.65 ±0.45	4.98 ±1.37

In Table 4 the percentage increases in yield are given for the different treatments, based on the yield of the check as determined by harvesting the entire tenth-acre plots. Using 15.70 percent as the least increase that is probably significant for the tenth-acre plots and 9.49 percent, 12.73 percent, and 14.44 percent, respectively, for the 9, 5, and 4 rod rows removed from the tenth-acre plots, it is evident that treatment A is not significantly better than the check as indicated by the yields ascertained by each of the four methods. With the exception of treatment C, which shows only 13.68 percent increase

over the check as determined by harvesting the entire tenth-acre, and treatments B and C where 4 rod rows were removed from each plot, treatments B, C, D, and E show significant increases by each method.

TABLE 4.—*Comparison of the percentage increase in the yields of wheat for each fertilizer treatment based on the mean yield of the check at the Morris substation.*

Treatment.	Tenth-acre plots.	Increase in yield over the check as determined by harvesting the stated number of rod rows from each tenth acre.		
		Nine rod rows	Five rod rows.	Four rod rows
	Percent.	*Percent*	*Percent.*	*Percent.*
A	9.62	7.25	7.72	6.75
B	19.02	13.30	16.28	9.72
C	13.68	14.24	16.09	11.97
D	29.71	24.17	22.42	26.27
E	23.62	26.85	33.76	18.33

TABLE 5.—*Comparison of yields and variability of Haynes Bluestem (Minnesota No. 169) wheat grown at University Farm, St. Paul, Minn., under six different treatments as determined from triplicate tenth-acre plots and from 9, 5, and 4 rod rows removed from tenth-acre plots.*

Fertilizer treatment.	Source	Yield in bushels per acre for each of the triplicate plots.			Means.	Standard deviation	Coefficients of variability
Check	Tenth-acre plots	29.78	36.24	27.28	31.30±1.39	3.58±0.99	11.44±3.19
	Nine rod rows	40.97	40.58	33.21	38.25±1.39	3.57±0.98	9.33±2.57
	Five rod rows....	38.38	41.37	37.30	39.02±0.67	1.72±0.47	4.41±1.21
	Four rod rows .	35.06	39.41	27.92	34.13±1.85	4.74±1.31	13.89±3.90
A	Tenth-acre plots	35.05	31.33	35.79	34.06±0.76	1.96±0.54	5.75±1.58
	Nine rod rows	37.53	36.97	41.01	38.80±0.86	2.21±0.61	5.70±1.57
	Five rod rows	38.11	35.37	42.88	38.79±1.21	3.10±0.85	7.99±2.20
	Four rod rows ..	36.16	38.81	40.50	38.49±0.70	1.79±0.49	4.65±1.28
B	Tenth-acre plots.	33.59	32.77	35.53	33.96±0.45	1.16±0.32	3.42±0.94
	Nine rod rows ..	36.34	35.66	36.54	36.25±0.16	0.41±0.11	1.13±0.31
	Five rod rows. .	38.20	35.13	35.67	36.23±0.52	1.34±0.32	3.69±1.02
	Four rod rows....	35.04	36.16	37.46	36.22±0.39	0.99±0.27	2.73±0.75
C	Tenth-acre plots..	33.54	32.59	34.78	33.64±0.35	0.90±0.25	2.68±0.74
	Nine rod rows.. .	33.48	35.12	39.70	36.10±1.02	2.63±0.72	7.29±2.01
	Five rod rows ..	33.02	37.00	40.85	36.96±1.25	3.20±0.88	8.66±2.38
	Four rod rows ..	33.91	32.61	37.90	34.81±0.88	2.25±0.62	6.46±1.78
D	Tenth-acre plots..	34.92	31.57	36.55	34.35±0.81	2.07±0.57	6.03±1.66
	Nine rod rows....	38.69	31.67	39.69	36.68±1.39	3.57±0.98	9.73±2.68
	Five rod rows....	40.07	30.82	43.61	38.17±2.10	5.39±1.48	14.12±3.96
	Four rod rows....	36.80	32.37	34.61	34.59±0.70	1.81±0.50	5.23±1.44
E	Tenth-acre plots..	33.73	30.78	36.51	33.67±0.91	2.34±0.64	6.95±1.91
	Nine rod rows....	34.85	32.89	37.23	34.99±0.69	1.77±0.49	5.06±1.39
	Five rod rows....	33.05	31.43	38.02	34.16±1.09	3.81±0.77	8.23±2.27
	Four rod rows....	36.96	34.57	36.08	35.87±0.39	0.99±0.27	2.76±0.76

RESULTS WITH WHEAT AT UNIVERSITY FARM.

The yields for the individual plots for each treatment of wheat at University Farm, with the mean, standard deviation, and coefficient of variability, are given in Table 5.

Due to the higher yield of the border rows in plots separated by alleys as compared with the rows farther within the plots, the expectation is that the yields from harvesting the entire plots will be higher than from harvesting all or portions of the interior of the same plots. Here the yields from harvesting the entire plots are lower than those secured by harvesting portions of the interior of the same plots (1). In this instance, the difference may be due in part to the loss of grain in harvesting with the binder, as the wheat was of the easily shattering Bluestem variety and was badly lodged. In Table 6 are given the percentage increases in yield for each treatment based on the mean yield of the check plots.

TABLE 6.—*Comparison of the percentage increases in the yields of wheat for each fertilizer treatment based on the mean yields of checks at University Farm.*

Treatment.	Tenth-acre plots.	Increase in yield over the check as determined by harvesting the stated number of rod rows from each tenth acre.		
		Nine rod rows.	Five rod rows.	Four rod rows.
	Percent.	*Percent.*	*Percent.*	*Percent.*
A	8.82	1.44	—	10.83
B	8.50	—	—	4.29
C	7.48	—	—	0.23
D	9.74	—	—	—
E	7.57	—	—	3.28

The yields from harvesting the entire plots show some increase in yield for each treatment as compared with the yield of the check, but the increase is not a significant one in any instance. For the 9-row method except for treatment A, the yield of the check is greater than the yield from the treated plots. For the 5-row method the yield of the check is higher than for any of the treated plots. No significant increases in yields due to treatment are indicated by the 4-row method.

RESULTS WITH OATS AT UNIVERSITY FARM.

Inspection of the mean yields for the three similarly treated plots as determined by the four methods shows the yields ascertained by the 5-row method to be as high or higher than those from the tenth-acre plots, while the yields from the four and nine rod rows are lower. This suggests a possible border effect in oats on the fifth row from the sides of the plots. The data on yields are given in Table 7.

TABLE 7.—*Comparison of yields and variability of Ligowa (Minnesota No. 281) oats grown at University Farm, St. Paul, Minn., under six different fertilizer treatments as determined from triplicate tenth-acre plots and from 9, 5, and 4 rod rows removed from tenth-acre plots.*

Fertilizer treatment.	Source	Yield in bushels per acre for each of the triplicate plots			Means	Standard deviations.	Coefficients of variability.
Check	Tenth-acre plots	77.83	73.31	80.72	77.29 ± 1.19	3.05 ± 0.84	3.95 ± 1.09
	Nine rod rows	84.61	67.80	75.87	76.11 ± 2.66	6.84 ± 1.88	8.99 ± 2.48
	Five rod rows	83.68	73.34	83.32	81.78 ± 2.48	6.36 ± 1.75	7.78 ± 2.14
	Four rod rows	79.63	61.09	63.38	68.03 ± 3.21	8.25 ± 2.27	12.13 ± 3.39
A	Tenth-acre plots	82.67	80.64	81.48	81.60 ± 1.02	2.63 ± 0.72	3.22 ± 0.89
	Nine rod rows	83.23	70.38	85.13	79.58 ± 2.55	6.55 ± 1.80	8.23 ± 2.27
	Five rod rows	92.14	75.50	85.12	84.25 ± 2.66	6.82 ± 1.88	8.09 ± 2.23
	Four rod rows	72.20	64.07	85.25	73.84 ± 3.40	8.72 ± 2.40	11.81 ± 3.30
B	Tenth-acre plots	85.76	77.98	79.90	81.21 ± 1.29	3.31 ± 0.91	4.08 ± 1.12
	Nine rod rows	86.97	74.70	81.21	80.96 ± 1.95	5.01 ± 1.38	6.19 ± 1.70
	Five rod rows	88.29	77.07	84.87	83.41 ± 1.83	4.70 ± 1.29	5.63 ± 1.55
	Four rod rows	85.44	71.82	76.73	78.00 ± 2.19	5.63 ± 1.55	7.22 ± 1.99
C	Tenth-acre plots	86.02	79.25	80.79	82.02 ± 1.13	2.90 ± 0.80	3.54 ± 0.97
	Nine rod rows	84.36	78.46	80.22	81.01 ± 0.96	2.47 ± 0.68	3.05 ± 0.84
	Five rod rows	83.31	82.85	83.27	83.14 ± 0.08	0.21 ± 0.06	0.25 ± 0.07
	Four rod rows	85.79	73.06	76.52	78.46 ± 2.09	5.37 ± 1.48	6.84 ± 1.88
D	Tenth-acre plots	85.64	76.73	87.88	83.41 ± 1.88	4.82 ± 1.33	5.78 ± 1.59
	Nine rod rows	79.87	72.78	86.93	79.86 ± 2.25	5.78 ± 1.59	7.24 ± 1.99
	Five rod rows	83.08	75.34	91.40	83.27 ± 2.55	6.56 ± 1.81	7.88 ± 2.17
	Four rod rows	75.95	69.68	81.45	75.69 ± 1.87	4.81 ± 1.32	6.35 ± 1.75
E	Tenth-acre plots	77.92	77.11	86.19	80.40 ± 1.60	4.10 ± 1.13	5.10 ± 1.40
	Nine rod rows	75.82	77.75	85.40	79.66 ± 1.61	4.14 ± 1.14	5.20 ± 1.43
	Five rod rows	78.71	77.61	86.32	80.88 ± 1.51	3.87 ± 1.07	4.78 ± 1.32
	Four rod rows	72.31	78.01	84.36	78.23 ± 1.92	4.92 ± 1.35	6.28 ± 1.73

TABLE 8.—*Comparison of the percentage increase in the yields of oats for each fertilizer treatment based on the mean yields of the checks at University Farm.*

Treatment.	Tenth-acre plots	Increase in yield over the check as determined by harvesting the stated number of rod rows from each tenth acre		
		Nine rod rows.	Five rod rows	Four rod rows
	Percent.	*Percent*	*Percent.*	*Percent*
A	5.58	4.56	3.02	8.58
B	5.07	6.37	1.99	14.66
C	6.12	6.44	1.66	15.33
D	7.92	4.93	1.82	11.26
E	4.02	4.66	——	14.99

The percentage increase in yield for each treatment over the mean yield of the checks is given in Table 8. The moderate tho not sig-

nificant increases in yield for all treatments are very similar for the plot and the 9-row methods. Still less increase in yield for the treatments is indicated by the 5-row method. By the 4-row method, B, C, and E gave significant increases in yield. At University Farm there was no significant increase due to the use of fertilizer treatment on oats.

RESULTS WITH OATS AT THE DULUTH SUBSTATION.

The yields for the three similarly treated plots with their constants are given in Table 9. The rod rows were removed from the plots at this location a week before the entire plots were harvested and while

TABLE 9—*Comparison of yields and variability of Ligowa (Minnesota No. 281) oats grown at the Duluth substation under six different treatments as determined from triplicate tenth-acre plots and from 9, 5, and 4 rod rows removed from tenth-acre plots.*

Fertilizer treatment	Source.	Yield in bushels per acre for each of the triplicate plots			Means.	Standard deviations	Coefficients of variability.
Check	Tenth-acre plots	——	60.70	60.70	60.70±0.00	0.00±0.00	0.00±0.00
	Nine rod rows . .	62.15	69.89	64.64	65.55±1.25	3.21±0.88	4.90±1.35
	Five rod rows . .	61.41	68.34	60.92	63.56±1.32	3.39±0.93	5.33±1.47
	Four rod rows	63.16	71.83	69.38	68.12±1.42	3.65±1.01	5.36±1.48
A	Tenth-acre plots	39.00	54.91	69.36	54.42±4.83	12.40±3.41	22.79±6.59
	Nine rod rows	77.84	62.34	69.13	69.77±2.47	6.34±1.75	9.09±2.50
	Five rod rows .	80.96	67.58	70.41	72.98±2.24	5.76±1.59	7.89±2.17
	Four rod rows. .	74.04	55.87	67.61	65.84±2.93	7.52±2.07	11.42±3.19
B	Tenth-acre plots .	52.03	54.92	69.37	58.77±2.96	7.59±2.09	12.91±3.61
	Nine rod rows	86.59	79.57	72.34	79.50±2.27	5.82±1.60	7.32±2.02
	Five rod rows . .	86.45	72.19	51.76	70.10±2.42	6.22±1.71	8.87±2.44
	Four rod rows . .	86.87	88.90	73.27	83.01±2.70	6.94±1.91	8.36±2.30
C	Tenth-acre plots	46.25	66.48	66.48	59.74±3.72	9.54±2.63	15.97±4.51
	Nine rod rows	72.65	88.81	79.87	80.44±2.57	6.61±1.82	8.22±2.26
	Five rod rows	77.14	88.14	76.80	80.69±2.05	5.27±1.45	6.53±1.80
	Four rod rows	67.13	89.78	83.81	80.24±3.73	9.59±2.64	11.95±3.34
D	Tenth-acre plots	52.03	54.92	69.37	58.77±2.96	7.59±2.09	12.91±3.61
	Nine rod rows . . .	75.96	75.90	82.84	78.23±1.27	3.26±0.90	4.17±1.15
	Five rod rows . .	77.85	74.78	90.41	81.01±2.63	6.76±1.86	8.34±2.30
	Four rod rows	73.70	77.38	73.49	74.86±0.70	1.79±0.49	2.39±0.66
E	Tenth-acre plots	60.70	60.70	66.48	62.63±1.06	2.72±0.75	4.34±1.20
	Nine rod rows. . .	78.48	83.61	58.35	73.48±4.24	10.90±3.00	14.83±4.17
	Five rod rows .	77.34	81.24	57.57	72.05±4.03	10.36±2.85	14.38±4.04
	Four rod rows . .	80.00	86.68	59.40	75.36±4.52	11.61±3.20	15.40±4.34

the oats were still slightly green. The third plot receiving treatment E is located on low ground and the oats was considerably more immature at the time the rows were removed than it was on the other plots.

In consequence the yield is low. This plot should have been allowed to stand for at least a week and another trip made to remove the rod rows from it.

The first of the three check plots was injured between the time the rows were removed and the harvesting of the entire plots and the yield is therefore omitted.

The percentage increases in yields are given in Table 10. No significant benefit is shown for the treatments by the yields secured from the entire plots. The 9-row method shows significant increases in yield from treatments B, C, D, and E. The 5-row method indicated that treatments C and D gave significant increases in yield. The 4-row method indicates a significant increase in yield from treatment B and a near approach to it from treatment C.

TABLE 10.—*Comparison of the percentage increase in the yields of oats for each fertilizer treatment based on the mean yields of the checks at the Duluth substation.*

Treatment	Tenth acre plots.	Increase in yield over the check as determined by harvesting the stated number of rod rows from tenth acre.		
		Nine rod rows	Five rod rows.	Four rod rows.
	Percent.	*Percent.*	*Percent.*	*Percent.*
A	——	6.44	14 82	——
B	——	21 28	10.29	21.84
C	——	22.72	26 95	17.79
D	——	19.34	27 45	9.89
E	3.18	12.10	13.36	10 63

MAN LABOR REQUIREMENTS IN HARVESTING AND THRASHING PLOTS AND ROWS.

The labor requirements at University Farm in 1917 for harvesting the entire tenth-acre plots as compared with removing 9 rod rows from the same tenth-acre plots varied with the condition of the straw. The oat crop stood up straight and, therefore, required less labor in harvesting than was necessary for the wheat, which was lodged badly. The amount of work that can be accomplished by a crew depends upon its personnel and on the organization and facilities. Other workers may find that the time for the operations as given is more than is needed or not enough. As is shown in Table 11, harvesting 9 rod rows from a plot required approximately the same amount of man labor as harvesting the entire plot with a binder. Thrashing each of the 9 rod rows from a plot by beating the grain out by hand and weighing the product from each row separately required as much man labor as thrashing the product of the entire plot with a large machine. Using a small thrasher which delivers the grain free from

straw and chaff would lower considerably the combined time given for thrashing and weighing in the row method. In the actual use of rod rows or small areas of other shape removed from plots to determine yields, the product of the several small areas would be combined at harvest. In this way, the time required for harvesting, thrashing, and weighing would be materially reduced.

TABLE 11.—*Comparison of the man-labor requirements of harvesting, thrashing and weighing grain from entire tenth-acre plots and from nine rod rows removed from the same plots.*

Operation.	Necessary crew.		Man hours per plot.	
	Men.	Horses.	Grain standing.	Grain lodged.
Tenth-acre plots:				
Harvesting	3	2	1.00	1.50
Thrashing and weighing	10	8	1.33	1.33
Nine rod rows:				
Harvesting	1	0	1.00	1.50
Thrashing and weighing	1	0	1.33	1.33

SUMMARY.

1. In the direct comparison of yields to find the value of fertilizer treatments, increases over the mean yield of the checks of 15.70 percent for the triplicate tenth-acre plots, 9.49 percent for the 9 rod rows, 12.73 percent for the 5 rod rows, and 14.44 for the 4 rod rows removed from three similarly treated tenth-acre plots are, on the average, probably significant. For the work at the Duluth substation, increases in yield over the checks of 32.40 percent for the tenth-acre plots and 12.34 percent, 16.56 percent, and 18.51 percent, respectively, for the 9, 5, and 4 rows removed from the plots seem necessary in order to be reasonably certain that the treatment is responsible for the differences.

2. For the wheat at the Morris substation, a significant increase in yield for treatment B was indicated by the entire plots and by the 9-row and 5-row methods and for treatment C by the 9 and 5 rod rows. Treatments D and E gave a significant increase in yield by each of the four methods.

3. For the wheat at University Farm, moderate but not significant increase in yield is indicated for each treatment from harvesting the entire plot. From the yields of the 9, 5, and 4 rod rows, no increases due to the treatments are indicated.

4. For the oats at University Farm, very similar but not significant increases in yields in percentage are indicated by harvesting the entire plots and by the 9 rod rows removed from them. The 5 rod rows in-

dicate less and the 4 rod rows indicate more increase for the treatments than is indicated by the entire plots.

5. At the Duluth substation no increases in yield due to treatments are indicated by harvesting the entire plots. The 9 rod rows indicate significant increases in yields for treatments B, C, D, and E and the 5 rod rows for treatments C and D. The 4 rod rows indicate increased yield for treatment B.

6. The man labor required to remove 9 rod rows from a tenth-acre plot, thrash these separately by hand, and weigh them is approximately the same as to harvest and thrash the entire plot. Using the rod-row method of ascertaining yields requires no horse labor and practically no machinery.

Conclusions.

From the evidence submitted, it seems fair to conclude that, for the conditions under which the work was done, 9 rod rows removed from tenth-acre plots gave practically as accurate indications of the value of fertilizer treatments as harvesting the product of the entire plots.

This method of determining yields may be used to advantage in drilled grain in locations where facilities are lacking for harvesting and thrashing accurately the products of the entire areas. The amount of man labor required to determine yield by the plot and row methods is practically equal.

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AGRONOMIC AFFAIRS.

OUTLOOK FOR 1919.

With the close of the war will come abundant opportunity for extension of agronomic work and experimentation, necessitating the employment of many additional men in agronomic lines. This extension of agronomic endeavor widens the field for the American Society of Agronomy, and to our Society there should come a large growth in membership and power during the next few years. Each of the present members should make a special effort to bring the Society to the attention of agronomic workers in their institution, for every member added to our list enables your officers to render a little more service to all by printing a larger and better journal. The editor of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY bespeaks your active cooperation for 1919 in bringing the Society and its publication to the position each should occupy among American scientific organizations and journals. This cooperation can be given along three lines, (1) by sending your own membership dues for the year promptly to the secretary-treasurer, (2) by urging other workers to join, and (3) by sending papers to the editor for publication. Let us all get together and make 1919 by far our best year!

DELAY IN DECEMBER NUMBER.

Because of the postponement of the meetings of agricultural college and experiment stations workers and, with them, the meeting of the American Society of Agronomy, the publication of the December issue of the JOURNAL has been greatly delayed. This number is now in press, however, and will be ready for mailing soon. It will contain the president's annual address, the reports of officers and committees, minutes of the annual meeting, and title pages and index for Volume 10.

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NITROGEN RELATIONS OF CERTAIN CROP PLANTS WHEN GROWN ALONE AND IN ASSOCIATION.[1]

R. C. WRIGHT.

A knowledge of the behavior of leguminous and nonleguminous plants when grown in association is of practical and also of considerable scientific interest. The investigations recorded here were prompted by the comparatively recent work in this country reported principally by Lyon and Bizzell, Lipman, and Westgate and Oakley. An examination of the results of these workers shows that very often the nitrogen composition of a nonlegume is increased when grown with a legume, tho this is not always the case. Apparently much depends upon the climatic and soil conditions under which legume-nonlegume mixtures are grown as well as upon the composition of the mixtures themselves.[2] Westgate and Oakley incorporate a fortunate note of warning in their conclusion:[3]

> The data . . . would seem to indicate that the phenomenon of increased protein content in the nonlegume by reason of its association with the legume is not so universally true as to make it safe to advocate the method unreservedly as a means of increasing the production of protein upon the farms of this country.

[1] These investigations were conducted under the direction of Karl F. Kellerman, Bureau of Plant Industry, U. S. Department of Agriculture. The paper was received for publication September 12, 1918.

[2] Kellerman, K. F., and Wright, R. Claude. Mutual influence of certain crops in relation to nitrogen. *In* Jour. Amer. Soc. Agron., v. 6, nos. 4–5, p. 204–210. 1914.

[3] Westgate, J. M., and Oakley, R. A. Percentage of protein in nonlegumes and legumes when grown alone and in association in field mixtures. *In* Jour. Amer. Soc. Agron., v. 6, nos. 4–5, p. 210–215. 1914.

The author has noted a rather reckless tendency of some popular writers to recommend the growing of mixtures of nonlegumes and legumes which have not been carefully tested. One such writer advocated the growing of corn and soybeans together, stating that besides increasing the protein value of the corn the beans would fix more than enough nitrogen in the soil to account for that removed in the growth of both corn and beans. It seemed to the writer that, as much of the work already reported upon has been conducted in the field, possibly more investigations should be made under strictly control conditions, thus insuring against nonuniformity of soil. The experiments here reported were conducted at the Arlington Farm of the United States Department of Agriculture during 1914 and 1915. The test crops were grown in galvanized corrugated iron buckets 15 inches in diameter by 13 inches deep. These buckets hold from 100 to 120 pounds of soil, depending on its character. All were housed in a cage built of 1-inch pipe covered with wire netting. The buckets were watered to weight daily with distilled water. Further description of the construction of the cage and the handling of the containers is given in another paper.[4] Plate 1 shows the manner of growing the crops in these experiments.

The soil used was screened, shoveled over several times on a cement floor, and equal quantities then weighed into the buckets. Leguminous and nonleguminous crops were grown both alone and in combination. When grown in combination half as many plants of each crop were grown in each bucket as when grown alone. After reaching maturity each crop, regardless of the accompanying crop, was harvested close to the surface of the soil and dried, weighed, and ground fine for analysis of total nitrogen. When all were harvested the roots were removed from the soil in each bucket and after being dried and ground were returned and thoroly mixed with the soil to allow more uniform sampling. Samples of soil were then removed and air-dried for nitrogen analysis.

All nitrogen results reported constitute the average of two closely agreeing determinations on 1-gm. samples of crops and 10-gm. samples of soil. Determinations on crop samples were made by the Gunning method, on soil samples by the Kjeldahl-Gunning-Jodlbauer method, using with both methods the sulfate mixture recommended by Lipman and Sharp.[5] Nitrates were determined in duplicate by a modifica-

[4] Wright, R. Claude. Growing plants in large containers under control conditions. *In* Jour. Amer. Soc. Agron., v. 8, no. 2, p. 113–116. 1916.

[5] Lipman, C. B., and Sharp, L. T. Toxic effects of "alkali salts" in soils on soil bacteria. III. Nitrogen fixation. *In* Centr. Bakt., Abt. 2, 35: 648. 1912.

Pots of soybeans and oats, showing manner in which crops were grown.

tion of the Ulsch method, reduction taking place over night in acidified soil extracts in presence of iron dust. The operation may briefly be described as follows: One hundred grams air-dry soil is shaken at frequent intervals for a half hour with 300 c.c. of distilled water and about a gram of calcium oxide. The extract is then filtered, measured, and acidulated with 3 c.c. sulfuric acid; about 2 gm. of iron dust are added and reduction allowed to take place over night in the cold. Approximately 8 gm. of magnesium oxide are then added and ammonia distilled off in the usual way.

Experiments in 1914.

In 1914 the soil used was a clay loam which had been composted with manure and left in a pile for several years. A quantity of this soil was limed and thoroly stirred, after which equal quantities representing 45 kg. when brought to the optimum moisture condition were weighed into the buckets. The crops grown this season were spring oats, spring barley, spring rye, and dwarf kafir, each grown in association with hairy vetch, field peas, and red clover. Corn was also grown both with oats and pearl millet. Each of these crops named was also grown alone. All combinations were planted in duplicate buckets, while quadruplicates were planted to each variety when grown alone, as these also served in another investigation carried on simultaneously.

Table 1 shows the yields in dry matter of all the crops both when grown alone and when grown in association. These will be considered in conjunction with Table 2 and figure 3, showing the average yields in weight of nitrogen. In examining these and subsequent results one should bear in mind that, as previously stated, when grown in combinations half as many plants of each crop was used as when grown alone, thus assuring more equal conditions for each crop than if the same number of plants of each variety were grown in combination as when grown alone. Considering the results as a whole, the nonlegumes in most cases when grown in combination with legumes made nearly as much dry matter and weight of nitrogen as when grown alone. The legumes used, being generally less vigorous growers, possibly suffered at the expense of the nonlegumes by the association.

Taking the results in order, barley in combination with hairy vetch, field peas, and red clover made practically as much dry matter as when grown alone. Vetch and clover in these combinations also made nearly as much dry matter as when grown alone. These two

combinations with barley seemed to be particularly favorable, especially barley and clover. The total yield of dry matter from the barley and vetch combination equaled 159.5 gm., while that from barley and clover was 181 gm. Barley alone yielded 118.2 gm.; vetch, 77.5 gm.; and clover 94.0 gm.

TABLE I.—*Dry weights in grams of various crops when grown alone and in association with other crops.*[a]

Crop.	Grown alone.	Grown in association with—							
		Vetch.		Field peas.		Red clover.		Corn.	
		Weight of crop.	Combined weight.[b]	Weight of crop.	Combined weight.[b]	Weight of crop	Combined weight.[b]	Weight of crop	Combined weight.[b]
Barley	118.2	105.3	159.5	115.4	116.7	115.0	181.0		
Rye	43.5	38.7	120.1	21.9	29.0	30.7	108.4		
Oats	145.6	123.5	126.2	136.3	140.8	128.5	193.7	61.0	265.6
Kafir	357.0	298.0	330.9	296.0	308.8	266.3	288.6		
Millet	308.5							84.4	317.5

Crop.	Grown alone.	Grown in association with—				
		Barley.	Rye.	Oats.	Kafir.	Pearl millet.
Vetch	77.5	54.2	81.4	2.7	32.9	
Field peas	49.3	[c]1.3	7.1	4.5	12.8	
Red clover	94.0	66.0	77.7	65.2	22.3	
Corn	320.9			204.6		233.1

[a] Weights of crops grown alone are averages of yields from four cans and weights of crops grown in association are averages of duplicates, except as noted.

[b] Combined weights of associated crops.

[c] Yield from one can only.

The barley-vetch and barley-clover combinations also yeilded more grams of nitrogen than either grown alone. Barley and vetch equaled 3.65 gm. and barley and clover 3.89 gm., as against 2.16 gm. for barley alone, 2.18 gm. for vetch alone, and 2.45 gm. for clover alone. The growth of peas with barley was almost negligible, while barley in this combination practically equaled that when grown alone. When peas and barley were grown together the yield in nitrogen was only slightly greater than that from barley alone.

A comparative study of the amount of nitrogen remaining in the soil after these crops were grown as shown in figure 3 is of interest. In both the barley-vetch and barley-clover combinations, while the yield in grams of nitrogen is considerably larger than any of these crops grown alone, the amount of nitrogen left in the soil is also greater. In other words, these combinations remove less nitrogen

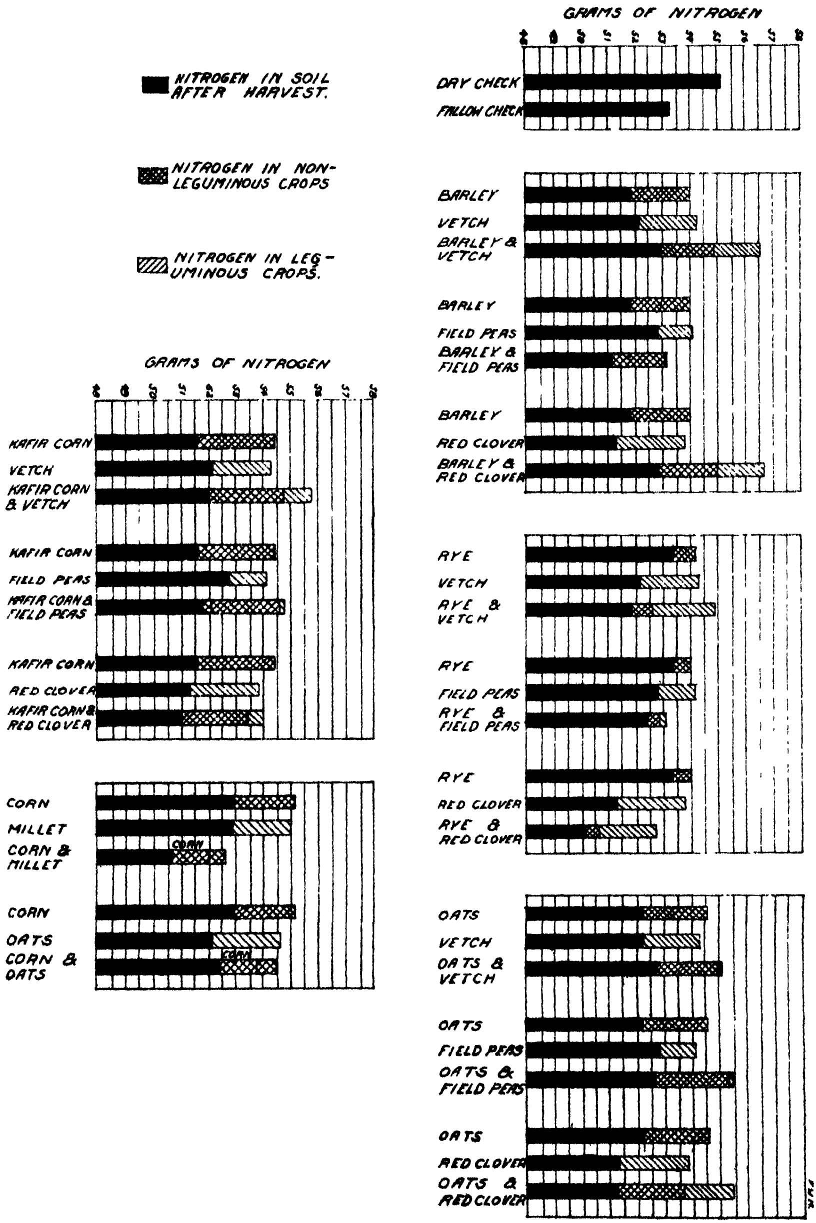

FIG. 3. Grams of nitrogen remaining in the soil after harvest and that recovered in the crops when grown both alone and in association.

from the soil than any of their components when grown alone and at the same time yield almost double the weight of nitrogen, the increased nitrogen in the yield having apparently been gained from the atmosphere through bacterial nitrogen fixation. With the barley-pea combination considerably more nitrogen was removed from the soil than was recovered, showing a distinct loss.

TABLE 2.—*Weight in grams of nitrogen in crops when grown alone and in association.*[a]

Crop.	Grown alone.	Grown in association with— Vetch. Nitrogen in crop.	Vetch. Combined weight.[b]	Field peas. Nitrogen in crop.	Field peas. Combined weight.[b]	Red clover. Nitrogen in crop.	Red clover. Combined weight.[b]	Corn. Nitrogen in crop.	Corn. Combined weight.[b]
Barley	2.16 ± 0.05	2.03 ± 0.28	3.65	2.23 ± 0.01	2.27	2.07 ± 0.04	3.89		
Rye	[c].83 ± .04	.70 ± .05	3.13	.41 ± .14	.60	.56 ± .08	2.60		
Oats	2.44 ± .02	2.39 ± .07	2.44	2.74 ± .03	2.84	2.38 ± .14	4.20	0.78 ± 0.04	2.08
Kafir	2.88 ± .13	2.72 ± .32	3.72	2.77 ± .03	3.01	2.47 ± .19	3.00		
Millet	2.10 ± .03							.59 ± .08	2.00

Crop.	Grown alone	Grown in association with— Barley.	Rye.	Oats.	Kafir.	Pearl millet
Vetch	2.18 ± 0.15	1.62 ± 0.25	2.43 ± 0.19	0.05 ± 0.02	1.00 ± 0.18	
Field peas	1.32 ± .25	[d].04	.19 ± .02	.10 ± .05	.24 ± .08	
Red clover	2.45 ± .05	1.82 ± .13	2.04 ± .21	1.82 ± .14	.53 ± .19	
Corn	2.15 ± .08			1.30 ± .06		1.41 ± 0.13

[a] Results reported for crops grown alone are averages of yields from four cans and those of associations are averages of yields from two cans, except as noted. The formula used in computing averages was $Rm = 0.845 \frac{\Sigma d}{n\sqrt{n-1}}$. Rm = probable error of the mean, Σd = sum of the departures, n = number of determinations.

[b] Combined weight of nitrogen in the two constituents.

[c] Average of three samples.

[d] One sample only.

Considering next the combinations with rye, we find that the rye-vetch combination gave the greatest quantity of dry matter, 120 gm., followed by the rye-clover combination with 108.4 gm., as against 43.5 gm. for rye, 77.5 gm. for vetch, and 94.0 gm. for clover when each was grown alone. In the rye-pea combination the dry matter from each component was materially reduced as compared with these when grown alone. The yield of nitrogen in the rye-vetch combination was somewhat greater than when either was grown alone. In the rye-pea combination the yield of nitrogen was less than when

either was grown alone, and at the same time more nitrogen was removed from the soil, showing a loss similar to that in the barley-pea combination. The rye-clover combination also shows a loss in soil nitrogen not recovered in the crops grown. This combination removed 3.25 gm. more nitrogen from the soil than the rye crop alone and only 2.60 gm. of this was recovered in the combination crop. In the light of our present knowledge this loss is unaccountable. It can not possibly be due altogether to error in analysis, as it occurs in several cases and all determinations were made in duplicate on at least two parallel samples.

The yield of dry matter in vetch and peas when grown with oats was almost negligible, while that from oats in the combinations was almost as great as when oats were grown alone. In neither combination did the yield in dry matter equal that when oats were grown alone. The dry matter from the oat-clover combination was considerably in excess of either grown alone, amounting to 193.7 gm. against 145.6 gm. and 94 0 gm. for oats and clover respectively when grown alone. The yield of nitrogen from oats and vetch when grown separately was practically the same; however, when grown in combination the nitrogen from vetch was almost nil. The combined weight of nitrogen was the same as that from oats alone, but the amount of nitrogen left in the soil under this combination was 0.6 gm. greater than that left by oats alone. The nitrogen in oats when grown with peas was greater than when grown alone, being 2.49 gm. when grown alone and 2.74 gm. when with peas. On the other hand, nitrogen in peas when grown alone was 1.32 gm. and was reduced to 0 10 gm. when grown with oats. As in the case of oats and vetch, this combination of oats and peas left more nitrogen in the soil than oats alone, altho the combined crop (in fact, the oats in the combination crop) contained more nitrogen than when oats were grown alone. In the oat-clover combination the nitrogen in the oats was practically the same as in oats grown alone. The combined weight of nitrogen was 4.20 gm. Very little more nitrogen was removed from the soil under the combination crop than under either of the single crops, altho the combination crop yielded nearly double the amount of nitrogen.

The combinations in which kafir entered did not yield as much dry matter as kafir grown alone. This possibly was due to some extent to the fact that the legumes used in these experiments normally yielded so much less gross dry matter than the kafir that when grown in association they were not able to make up for the deficiency caused by cutting the number of kafir plants in half. However, the kafir

was benefited at the expense of the legumes by the association, as the gross yields of dry matter were not very materially reduced as compared with this crop grown alone. On the other hand, the gross yields from the legumes were reduced more than half. The combined yields of nitrogen from these associations was greater than when any of the crops were grown alone.

When oats or pearl millet is grown with corn the yield of dry matter in these crops is greatly reduced, but the yield from corn is not proportionately reduced. The yield of nitrogen was less in both combinations of millet and oats with corn than in any of these grown alone. Under the corn-millet combination practically as much nitrogen was removed from the soil and not recovered in the crop as under rye and clover. In this case more was removed than by either corn or millet alone and the amount recovered in the combined crop was not equal to this difference.

TABLE 3.—*Percentage of nitrogen in various crops when grown alone and in association with other crops.*[a]

Crop.	Grown alone.	Grown in association with— Vetch.	Field peas.	Red clover.	Corn.
Barley	1.84 ± 0.03	1.92 ± 0.02	1.94 ± 0.05	1.80 ± 0.03	
Rye	[b]1.87 ± .01	1.82 ± .91	1.90 ± .01	1.82 ± .02	
Oats	1.68 ± .01	1.94 ± .04	2.01 ± .01	1.85 ± .00	1.29 ± 0.02
Kafir	.81 ± .02	.90 ± .04	.94 ± .08	.93 ± .03	
Pearl millet	.68 ± .01				.69 ± .00

Crop.	Grown alone.	Grown in association with— Barley.	Rye.	Oats.	Kafir	Pearl millet.
Vetch	2.82 ± 0.02	2.97 ± 0.17	2.99 ± 0.00	1.91 ± 0.10	3.10 ± 0.14	
Field peas	2.76 ± .07	[c]2.85	2.65 ± .07	2.24 ± .01	1.94 ± .06	
Red clover	2.61 ± .03	2.77 ± .10	2.64 ± .04	2.79 ± .03	2.44 ± .11	
Corn	.66 ± .01			.63 ± .01		0.60 ± 0.02

[a] Data for crops grown alone are averages of results from four cans, and those for crops grown in association are averages of duplicates, except as noted.
[b] Average of three samples.
[c] One sample only.

Table 3 and figure 4 show the percentage of nitrogen in the various crops grown alone in comparison with that when they are grown in association. In the barley-vetch and barley-pea combinations the percentage of nitrogen in both the barley and the legume was increased. When barley and clover was grown together the percentage of nitrogen in barley was decreased and in clover it was increased. In the rye-vetch combination the percentage of nitrogen was decreased in

rye and increased in vetch. In the rye-pea combination the percentage in rye was very slightly increased and that in peas decreased. In rye and clover the percentage in rye was again decreased and in clover slightly increased. In the oat-vetch combination the percentage of nitrogen was increased in oats and materially decreased in vetch. Likewise in oats and peas the percentage of nitrogen increased in oats and decreased in peas. In oats and clover the nitrogen percentage is increased in both constitutents. In the kafir-vetch combination both constituents increased in nitrogen percentage. The nitrogen percentage in kafir increased when grown with peas or clover, while it decreased in the legumes.

It will be noticed in figure 3, on comparing the nitrogen in the dry checks or original soil with that in the soil after growing the various crops, that in only a few cases was the nitrogen removed by a given crop recovered in that crop. In some of the combinations more nitrogen was recovered than was removed from the soil. In some cases, especially with barley and peas, rye and peas, rye and clover, and corn and millet, the loss in nitrogen was quite serious. The question of this loss of nitrogen will be dealt with at length in a later paper.

In conclusion, nine representative field crops were grown alone and in certain combinations in large galvanized iron buckets holding 45 kg. moist soil. When two species of plants were grown in association, half the number of plants of each was used as when grown alone. Crops were grown to maturity and harvested close to the surface of the soil. Roots were included with the soil. There was a distinct loss of nitrogen in the following combinations: Barley and peas, rye and peas, rye and clover, and corn and millet. There was a distinct gain in nitrogen with barley and vetch, barley and clover, oats and peas, oats and clover, and kafir and vetch. In general, when barley and vetch, barley and clover, oats and vetch, oats and peas, and kafir and vetch were grown together, altho more dry matter and nitrogen were produced, not so much nitrogen was removed from the soil as when these crops were grown alone.

Barley gained in percentage of nitrogen with vetch and peas while it lost with clover. Rye lost slightly with vetch and clover and gained slightly with peas. Both oats and kafir gained with vetch, peas, and clover. Simultaneously, vetch gained in percentage of nitrogen with barley, rye, and kafir, but lost with oats. Field peas gained with barley but lost with rye, oats, and kafir. Red clover gained with barley, rye, and oats but lost with kafir. Corn when

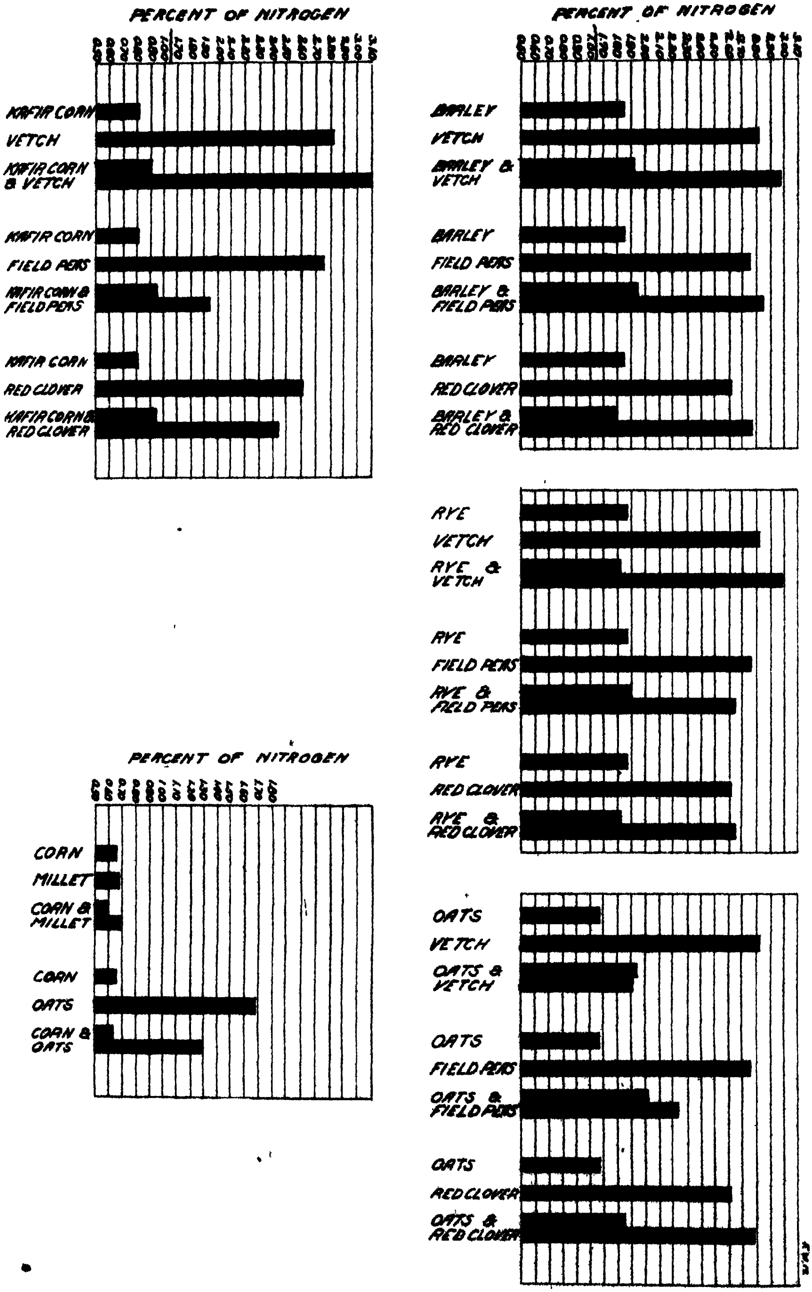

FIG. 4. Percentage of nitrogen in the crops when grown alone and in association.

grown both with millet and oats lost in percentage of nitrogen, while millet gained very slightly and oats lost materially.

Experiments in 1915

The next season's work (1915) was planned more to observe the comparative results of a few combinations in different types of soil rather than the results of a large number of combinations. Consequently only three nonlegumes and two legumes were grown, viz.: Spring oats, spring barley, kafir, soybeans, and purple vetch. These combinations allow comparisons between the growth of a nonlegume in association with a strong, vigorous-growing legume like the soybean, which is likely to compete very actively for plant food, and a weaker-growing legume like the vetch. We were unfortunate in the selection of the variety of oats (Sixty-Day), as it made only slight growth, maturing when the plants were quite small. These crops were grown in triplicate in three parallel series on the following types of soil: Semiarid, a coarse gravelly virgin loam from near Riverside, Cal.; Great Plains, a heavy black virgin loam from near Manhattan, Kans.; and eastern humid, a practically virgin clay loam from near Arlington, Va. In all other respects this experiment was handled the same as in 1914.

Table 4.—*Dry weight in grams of crops grown alone and in association in California, Kansas, and Virginia soil at Arlington Farm, Va.*[a]

NONLEGUMES.

Association.	Grown in Cal. soil.			Grown in Kansas soil.			Grown in Va. soil.		
	Oats.	Barley.	Kafir	Oats	Barley.	Kafir.	Oate.	Barley.	Kafir.
Grown alone	36.5	29 5	65.7	30 2	26.0	99.0	12.7	10.8	117.7
With soybeans	23.0	33.2	40.8	16.8	15.2	40.8	6.2	10.8	49.5
With vetch	27.0	20.2	38.7	21.5	15.2	100.5	10 7	9.3	72 7

Association.	Grown in Cal. soil.				Grown in Kansas soil.				Grown in Va. soil.			
	Soybeans.		Vetch.		Soybeans.		Vetch.		Soybeans.		Vetch.	
	Weight of crop.	Combined weight.[b]	Weight of crop.	Combined weight.[b]	Weight of crop.	Combined weight[b]	Weight of crop.	Combined weight.[b]	Weight of crop.	Combined weight.[b]	Weight of crop.	Combined weight.[b]
Grown alone	127.3		13.8		59.8		7.2		63.7		7.7	
With oats	51.2	74.2	12.7	39.7	38.5	55.3	9.3	30.8	44.3	50.5	4.0	14.7
With barley	53.0	86.2	6.7	26.9	31.7	46.9	7.7	22.9	40.5	51.3	2.8	12.1
With kafir	52.3	93.1	10.0	48.7	40.8	90.6	4.2	104.7	45.5	95.0	6.2	78.0

[a] All data reported are average yields of three cans.

[b] Combined weight of legume and nonlegume grown in association.

In Table 4 the weights of dry matter yielded by the crops grown alone and in association in the three soils are shown. No attempt will be made to draw comparisons between the yield of the different soils from the standpoint of determining their relative value or productiveness, as this obviously is not the purpose of the experiment. In all three soils the oat-soybean and barley-soybean combinations yielded less dry matter and weight of nitrogen than soybeans alone, due to the reduction in number of plants overbalancing any possible benefit to the remaining plants.

In California soil the yield of oats in association with soybeans was only slightly reduced, while that of soybeans was reduced more than half. The oat-vetch combination yielded a very slight increase over either grown alone in all the soils. The barley-soybean combination also showed a decreased yield as compared with soybeans alone. In California soil again the yield of beans was reduced more than half, but the yield of barley was slightly increased. In Kansas soil the yield of both barley and beans was reduced by apparently half, while in Virginia soil and yield of barley in the combination was the same as when grown alone and the yield of beans was reduced by about one-third.

In California soil the yield of barley with vetch was somewhat reduced, while the vetch was reduced by about half. The combination gave a yield of dry matter less than from barley alone. In Kansas soil the yield of barley was less in the combination and the yield of the combination was less than barley alone. In Virginia soil the yield from the combination was practically the same as from barley alone. The yield of vetch was less than half that when grown alone.

In the kafir-soybean combination in California soil the yield was less than from beans alone and greater than from kafir alone. However, while the yield of kafir was about one-third less than when grown alone, the yield of beans was over half less. In Kansas soil the yield of the combination was less than kafir alone and greater than soybeans alone. In this soil the yield of kafir in the combination was reduced more than half and the yield of beans less than one-third. In Virginia soil practically the same relations resulted in this combination as in Kansas soil. With the kafir-vetch combination practically the same relations resulted in California and Virginia soils. The combination yielded considerably more than vetch alone and less than kafir alone, while the yield of each in the combination was about one-third that when grown alone. In Kansas soil the yield from the combination was greater than that of either of the constituents grown alone.

Considering further relations between the various leguminous and nonleguminous crops in the different soils, it will be observed that in California soil oats when grown with purple vetch yields less dry matter than when grown with soybeans, a much larger and more vigorous crop which might be expected to compete more actively for plant food if plant food alone were the only controlling factor to be considered. Likewise barley and kafir produced less dry matter when grown with vetch. On the other hand, vetch made a better growth with oats than with either barley or kafir. These relations did not hold in Kansas soil. Here oats made a little better growth with vetch, barley made practically the same growth with beans and vetch, and kafir made almost double the growth with vetch that it did with beans. Soybeans with kafir made a better growth than with either of the less vigorous oats and barley. In Virginia soil these relations are not marked enough to call for special comment.

TABLE 5.—*Total nitrogen (in grams) in crops grown alone and in association in California, Kansas, and Virginia soil at Arlington Farm, Va.*[a]

Soil and association.	Nonlegumes.			Legumes.			
				Soybeans.		Vetch.	
	Oats.	Barley	Kafir.	Nitrogen in crop.	Combined weight.[b]	Nitrogen in crop.	Combined weight.[b]
California soil:							
Grown alone.	0.34 ±0.00	0.29 ±0.01	0.38 ±0.02	3.67 ±0.04		0.35 ±0.07	
With soybeans	.24 ± .02	.31 ± .01	[c].34				
With vetch...	.29 ± .01	.22 ± .01	.30 ± .02				
With oats....				1.74 ± .16	1.98	.34 ± .05	0.63
With barley..				1.77 ± .05	2.08	[c].19	.41
With kafir....				1.66 ± .12	2.00	.23 ± .04	.53
Kansas soil:							
Grown alone..	.55 ± .12	.53 ± .07	.94 ± .14	1.67 ± .14		.21 ± .01	
With soybeans	.33 ± .07	.30 ± .07	.38 ± .07				
With vetch...	.45 ± .01	.32 ± .07	1.01 ± .03				
With oats....				1.22 ± .13	1.55	.26 ± .01	.71
With barley..				1.02 ± .29	1.32	.21 ± .05	.53
With kafir....				1.30 ± .20	1.68	.09 ± .01	1.10
Virginia soil:							
Grown alone..	.30 ± .02	.32 ± .01	1.17 ± .06	1.88 ± .07		.26 ± .08	
With soybeans	.12 ± .01	.24 ± .01	.51 ± .01				
With vetch...	.26 ± .03	.27 ± .05	.89 ± .08				
With oats....				1.34 ± .10	1.46	.11 ± .02	.37
With barley..				1.22 ± .06	1.46	[c].07	.34
With kafir....				1.09 ± .04	1.60	.19 ± .02	1.08

[a] Data are averages of yields from triplicate cans, except as noted.
[b] Combined weight of associated legume and nonlegume.
[c] Average of two samples only.

Considering next the yield of nitrogen expressed in terms of grams of nitrogen yielded in each crop grown alone and in association, these results are shown in Table 5 and figure 5.

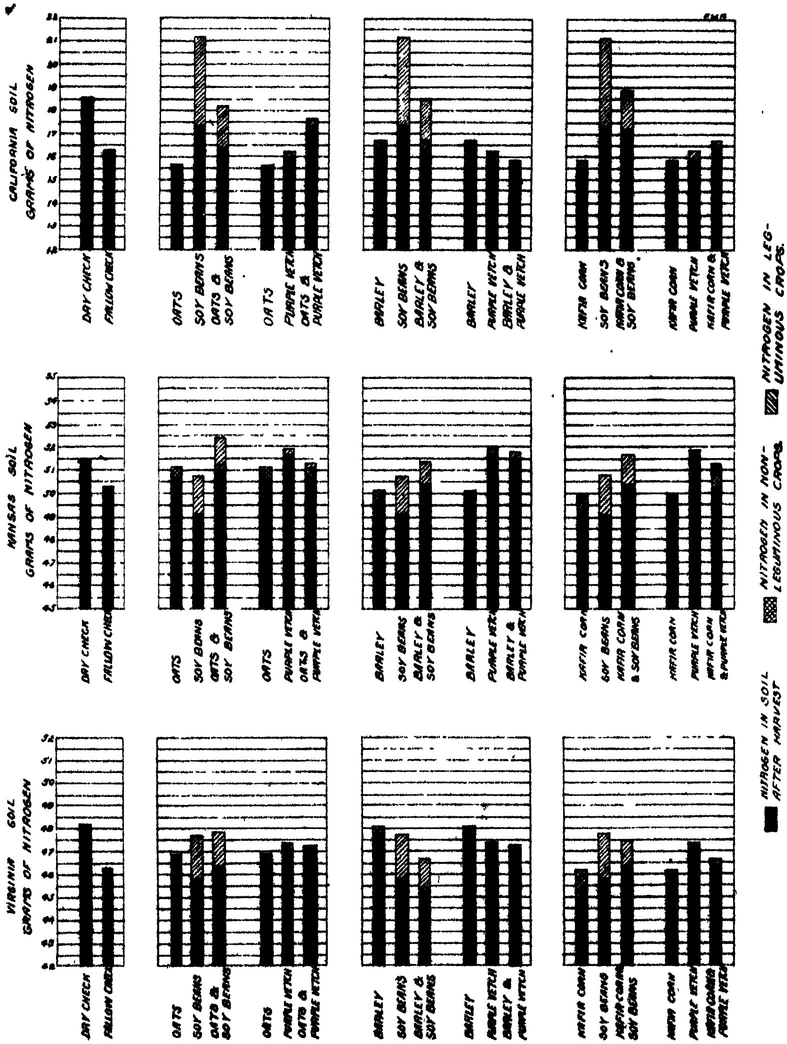

FIG. 5. Grams of nitrogen remaining in California, Kansas, and Virginia soil after harvest and that recovered in the crops when grown both alone and in association.

In California soil the relations of the combinations of soybeans with oats, barley, and kafir were much the same. Beans grown alone yielded considerably more nitrogen than any of the others grown alone. The weight of nitrogen yielded by the combinations was in every case greater than from the nonlegume grown alone and less

than from soybeans alone. At the same time more nitrogen was removed from the soil than by soybeans grown alone or by oats and kafir alone. The combination crops where purple vetch was grown with oats, barley, or kafir yielded somewhat more nitrogen than any of these grown alone. The oat-vetch and kafir-vetch combinations removed less nitrogen from the soil than any constituents grown separately. In the case of the barley-vetch combination more nitrogen was removed from the soil than by either constituent grown alone. While practically all the nitrogen removed from the soil by the growth of the combinations was recovered in the crop produced it is quite noticeable how much nitrogen was removed from the soil and not recovered by the crop in the case of oats, barley, kafir, and vetch grown alone.

In Kansas soil relations entirely different from those in California soil seemed to hold. The yield of nitrogen from the combinations of soybeans with oats, barley, and kafir was greater than from any of the nonlegumes and practically the same as from soybeans grown alone. At the same time less nitrogen was removed from the soil under these combinations than under any of the separately grown crops. Soybeans in this soil removed considerably more nitrogen than was recovered in the crop. The same was true of oats, barley, and kafir, but not to such a great extent as with soybeans or to such an extent as in California soil. There was a gain in nitrogen over that removed from the soil under the oats-soybean and kafir-soybean combinations. After growing vetch there still appeared to be a somewhat greater amount of nitrogen in the soil than in the original soil as represented by the dry check. Oats and vetch together yielded a slight increase in nitrogen over oats alone, altho no more nitrogen was removed from the soil. Barley and vetch together yielded the same amount of nitrogen as barley alone, but did not remove nearly as much nitrogen from the soil. Kafir and vetch together yielded more nitrogen than kafir alone and yet did not remove nearly as much nitrogen from the soil.

In Virginia soil soybeans in combination with oats, barley, and kafir yielded more nitrogen than any of these grown alone, but not so much as soybeans grown alone. The soybean-oat combination removed but little more nitrogen from the soil than oats alone and not so much nitrogen as soybeans alone. The soybean-barley combination removed considerably more nitrogen than barley alone and somewhat more than soybeans alone. The kafir-soybean combination removed about the same amount of nitrogen as soybeans alone and not so much as kafir alone. The oat-vetch and barley-vetch combina-

tion yielded a trifle more nitrogen than either alone. Oats-vetch removed a little more nitrogen from the soil than vetch alone and not so much as oats. Barley-vetch removed more nitrogen than either alone. Kafir-vetch did not remove as much nitrogen as kafir alone, but considerably more than vetch.

The last relations to be considered are the percentages of nitrogen in the different crops grown alone and in association. These are shown in Table 6 and figure 6.

TABLE 6.—*Percentage of nitrogen in crops grown alone and in association in California, Kansas, and Virginia soil at Arlington Farm, Va.*[a]

Soil and association.	Nonlegumes.			Legumes.	
	Oats.	Barley.	Kafir.	Soybeans.	Vetch.
California soil:					
Grown alone	0.94±0.01	0.99±0.02	0.58±0.01	2.89±0.06	2.47±0.11
With soybeans	1.09± .10	.94± .04	[b].64		
With vetch	1.07± .04	1.09± .02	.78± .08		
With oats				3.43± .07	2.66± .02
With barley				3.33± .02	[b]2.45
With kafir				3.17± .04	2.30± .09
Kansas soil:					
Grown alone	1.78± .11	2.06± .05	.95± .09	2.81± .05	2.88± .11
With soybeans	1.93± .02	1.98± .07	.93± .01		
With vetch	2.08± .07	2.03± .14	1.03± .10		
With oats				3.20± .08	2.80± .08
With barley				3.27± .07	2.73± .05
With kafir				2.52± .14	2.18± .05
Virginia soil:					
Grown alone	2.37± .05	2.92± .08	1.00± .07	2.96± .08	3.35± .16
With soybeans	2.00± .03	2.21± .08	1.06± .04		
With vetch	2.43± .07	2.92± .04	1.27± .10		
With oats				3.06± .10	2.69± .09
With barley				3.04± .16	[b]2.39
With kafir				2.40± .04	3.05± .10

[a] Data are averages of yields from triplicate cans, except as noted.
[b] Average of two samples only.

Considering first the results with California soil, the percentage of nitrogen in oats was increased both when grown with soybeans and vetch. Simultaneously, the nitrogen percentage was increased in both soybeans and vetch by the association. The percentage of nitrogen in barley was somewhat decreased when grown with soybeans, while that in the soybeans was increased. There was an increase in barley with vetch, while in vetch there was a slight decrease. When kafir was grown with soybeans and vetch the percentage of nitrogen was increased by the association, while in soybeans there was an increase and in vetch there was a decrease. In Kansas soil the percentage

of nitrogen was increased in oats when grown with soybeans and especially with vetch. It also was increased in soybeans when grown with oats, but was decreased in vetch. With barley the percentage

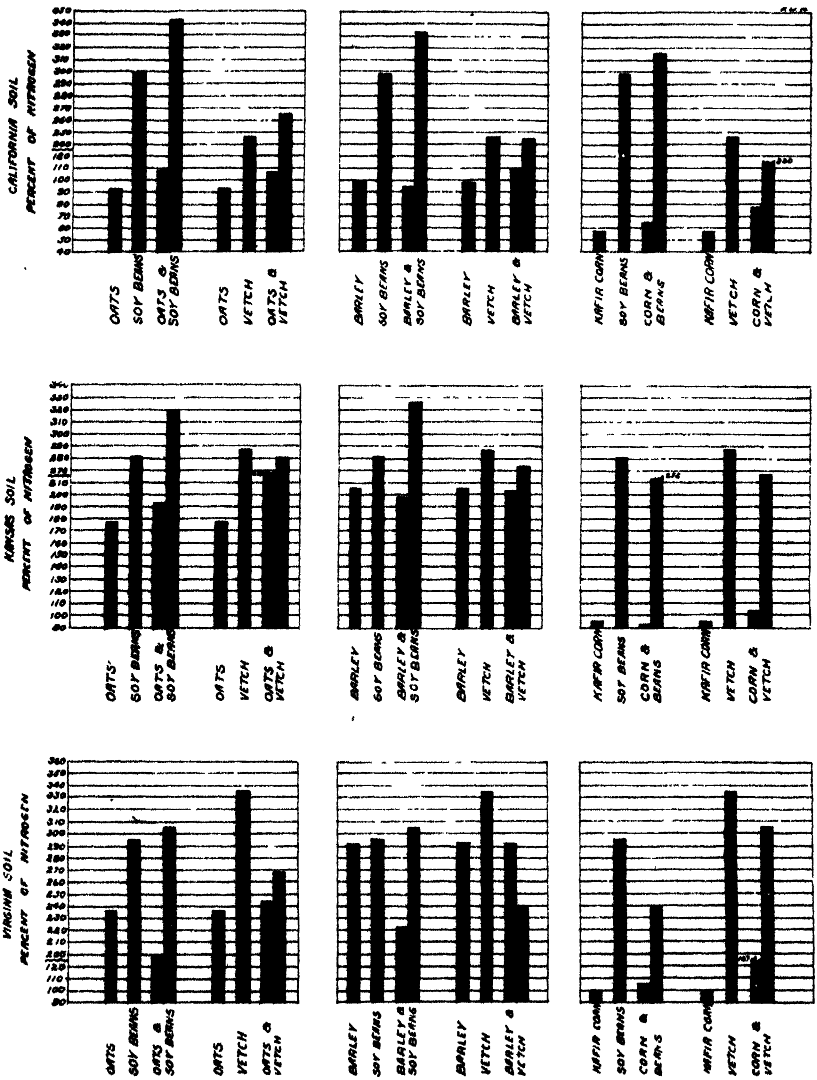

FIG. 6. Percentage of nitrogen in the crops grown alone and in association.

of nitrogen was reduced when grown both with soybeans and vetch, while that of soybeans was increased and vetch decreased by the association. There was a reduction in both when kafir and soybeans were grown together, but when kafir and vetch were grown together

there was an increase in the kafir and a decrease in vetch. In Virginia soil oats lost in percentage of nitrogen when grown with soybeans, while the beans gained somewhat. In the oat-vetch combination oats gained somewhat, while vetch lost considerably. Barley with soybeans lost considerably, while soybeans gained slightly. Barley when grown with vetch remained unchanged, while vetch lost considerably. With kafir and soybeans, kafir increased somewhat while soybeans lost considerably. Kafir also increased with vetch, while vetch lost.

In conclusion, legume-nonlegume combinations were grown with soybeans and purple vetch as the legumes and oats, barley, and kafir as the nonlegumes. The yield of dry matter, yield of total nitrogen, and percentage of nitrogen were compared when these crops were grown both alone and in association. Parallel experiments were conducted on three types of soil, semiarid from near Riverside, Cal., Great Plains from near Manhattan, Kans., and eastern humid from Arlington, Va. On each soil each crop was grown in triplicate in large galvanized buckets holding about 45 kg. of soil. Duplicate determinations for total nitrogen were made on the crop and soil from each bucket. The percentage of nitrogen in oats was increased when grown with soybeans and vetch in all soils except with soybeans in Virginia soil. Barley lost in percentage of nitrogen with soybeans in all soils. Barley gained with vetch in California soil, lost in Kansas soil, and remained unchanged in Virginia soil. Kafir gained in percentage of nitrogen with soybeans and vetch in all soils and with the exception of Kansas soil it lost with soybeans. Soybeans with oats and barley gained in all soils, while with kafir it gained in California and lost in Kansas and Virginia soil. Vetch with oats gained in California soil and lost in Kansas and Virginia soil. It lost with barley and kafir in all soils.

RUST RESISTANCE IN TIMOTHY.[1]

H. K. HAYES AND E. C. STAKMAN.

INTRODUCTION.

Among the first published papers on improvement in timothy is a short report by Hays (4)[2] of variations observed at the Minnesota station, together with a discussion of the possibilities of improving this crop. Extensive breeding studies with timothy have been carried on at the Cornell University station by Webber (10) and results of much promise have been obtained. A number of the improved sorts have given increased yield and also a better quality of hay than the commercial varieties. Aside from agronomic characters, such as stooling, height, and vigor, differences were observed in susceptibility to rust (*Puccinia graminis*). These differences in rust resistance were believed to be partially responsible for the yielding ability of these new sorts.

EXPERIMENTAL PLAN.

A project was outlined in 1916 for timothy selection studies at the Minnesota station. For the foundation stock 11 of the better Cornell sorts were obtained thru the kindness of Dr. C. H. Myers, who has charge of the timothy improvement work at Ithaca. Six of the better Minnesota selections were also grown. Seedlings were started in the greenhouse in the spring and approximately 125 plants of each selection were placed in. the field in rows 4 feet apart, the plants being spaced 3 feet apart in the row.

Correlated data were taken in 1917 on such important characters as yield, erectness, average length of head, height, number of stools, and resistance to rust. All of the above data except those on rust were taken on the first growth the latter part of June. Spores were then collected from an infected timothy field and as soon as the second growth of the plants was well started they were sprayed with rust spores and data taken some time later on the amount of infection. As nearly all plants of the Minnesota selections were heavily rusted the epidemic was considered to be a satisfactory one.

It was planned to take individual plant data in 1918 and then save

[1] Published with the approval of the Director as Paper No. 139 of the journal series of the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn. Received for publication, October 22, 1918.

[2] Figures in parentheses refer to "Literature cited," p. 69.

seed from a few of the better plants as determined by the correlated data for the two crop seasons. These selected plants were to be propagated by seed to determine transmission of their characters and by bulblets for the purpose of determining reliability of the data taken. Due to the severe winter of 1917, however, practically all of the plants were winterkilled. Because of the pressure of other work and the difficulty of obtaining field and laboratory assistants it seems impossible to repeat the experiment at this time. As some information regarding resistance has been obtained a short note is here presented.

EXPERIMENTAL RESULTS.

The plants were placed in four groups according to the amount of rust present, as follows: Group 1, no rust; group 2, slight infection; group 3, moderate infection; and group 4, heavily rusted.

The following data are given in Table 1: Number of plants in the different rust classes and average rust class, average yield per plant in pounds, average erectness with 1 as a basis of an erect plant and 10 a procumbent one, average length of head, average height in centimeters, and stooling.

TABLE 1.—*Rust resistance in timothy in relation to other characters, as shown by various data.*

Variety.	Rust classes.				Rust, mean.	Average yield per plant.	Erectness, mean.	Average length of head.	Average height.	Average number of stools.
	1.	2.	3.	4						
						Pounds.		*Cm.*	*Cm.*	
Cornell 1611	80	11	1		1.1	1.0	2.3	11.9	88	122
Cornell 1620	77	26	3	2	1.3	1.0	2.2	18.3	88	138
Cornell 1630	79	15	9	2	1.3	.9	3.1	12.3	85	141
Cornell 1635	61	14	9	3	1.5	.8	2.9	11.4	85	109
Cornell 1671	56	13	13	5	1.6	.8	2.9	11.6	89	123
Cornell 1676	87	10	3	6	1.3	.9	2.9	13.1	87	116
Cornell 1687	86	12	9	6	1.4	.9	3.7	11.3	88	131
Cornell 1715	90	11	6	3	1.3	.8	3.0	10.3	86	98
Cornell 1743	100	3	12	7	1.4	1.0	5.6	10.9	84	134
Cornell 1777	36		4		1.2	.9	5.7	11.5	83	142
Cornell 3230	32	5	5		1.4	.9	3.1	12.9	86	117
U. S. Dept. Sel. 1 ..	2	12	70	40	3.2	.6	2.6	13.0	91	64
U. S. Dept. Sel. 2....	4	4	19	13	3.0	.8	3.3	10.9	87	90
U. S. Dept. Sel. 3...		7	15	9	3.1	.8	2.8	13.3	92	72
L. L. May Sel. 1 ...	2	3	24	15	3.2	.6	2.3	12.4	86	70
L. L. May Sel. 2	8	5	25	6	2.7	.6	3.1	10.1	80	92
Griggs Bros. Sel. 1...	1	1	15	5	3.1	.7	3.0	12.8	86	91

The striking fact is that the Cornell selections show a high percentage of resistant plants, while the Minnesota selections are very susceptible. The Cornell and Minnesota selections average about the

same in height, although the former average somewhat higher in yield. Cornell types proved much superior in stooling ability; this may explain their higher yield. These results indicate that the production of a rust-resistant timothy could be very easily accomplished.

Breeding for disease resistance has given very promising results in some cases. Notable examples with economic plants as a result of hybridization are the work of Orton in producing a wilt-resistant watermelon by crossing a resistant citron and a susceptible watermelon (1) and Biffen's (2) production of a high-grade wheat resistant to yellow or stripe rust (*Puccinia glumarum*). Examples of improvement obtained by selection among economic plants are wilt resistance in cotton and other crops (7), wilt resistance in flax (3), and the production of a cabbage resistant to the Fusarium or yellows disease (5).

As Orton's wilt-resistant watermelon did not prove resistant on the Pacific Coast it seems logical to conclude that breeding for disease resistance is often a local problem. Bolley has shown that a variety of flax which is resistant may lose this quality if grown for a number of years on soil which is free from the disease-producing organism.

Experiments conducted cooperatively with the Office of Cereal Investigations, U. S. Dept. of Agriculture, at the Minnesota station (6, 8, 9) show the growing complexity of some problems in disease resistance. As an example, wheats which are susceptible in the Northwest to the black stem rust are resistant to the rust collected on the Pacific Coast or the Southeastern States. Different biologic forms are the cause of this variation in susceptibility. Recent studies have shown that there are many biologic forms of the wheat stem rust in the United States which can only be differentiated by their reaction to different host plants.

Data of this nature show the need of closer cooperation between investigators who are attacking the same general problem. Such cooperation would, we believe, prove of national significance and could be attained without serious less of prestige for each investigator concerned.

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THE EFFECT OF HEAT ON THE LIME REQUIREMENTS OF SOILS.[1]

H. A. NOYES.

Brown and Johnson[2] have found that the reaction of a soil by the Veitch method is changed by grinding the soil. Conner[3] has found that keeping soils at different moisture contents alters their acidities. Heat is known to have an effect on the hydrogen ion concentration of a soil.[4] In a previous paper[5] the present writer reported a soil giving an acid reaction by the Hopkins potassium-nitrate method[6] when, under field conditions, limestone fragments varying in size from a kernel of wheat to 2 cm. in diameter were present. The first step in

[1] Contribution from the Purdue University Agricultural Experiment Station, La Fayette, Ind. Received for publication July 31, 1918.

[2] Brown, P. E., and Johnson, H. W. Effect of grinding the soil on its reaction as determined by the Veitch method. *In* Jour. Ind. Eng. Chem., 7: 776, 777. 1915.

[3] Conner, S. D. Soil acidity as affected by soil moisture. *In* U. S. Dept. Agr., Jour. Agr. Research. *In press.*

[4] Sharp, L. T., and Hoagland, D. R. Acidity and adsorption in soils as measured by the hydrogen electrode. *In* U. S. Dept. Agr., Jour. Agr. Research, 7: 123–145. 1916.

[5] Noyes, H. A. Study of a soil containing residual limestone. *In* Jour. Assoc. Off. Agr. Chem., 3: 151–153. 1917.

[6] Official methods of analysis. U. S. Dept. Agr., Bur. Chem. Bul. 107, p. 20. 1908.

the determination of the acidity of the soil by the Veitch method[7] is to treat it with dilute limewater and evaporate the mixture to dryness on the steam bath. The work reported here was done to see if the evaporation on the steam bath caused changes that affected the acidity.

The soil was a residual silty clay loam containing about 60 percent of very fine silt and 20 percent of clay and is underlain with limestone rock. Samples were taken to represent different depths at different places, brought to the laboratory, air dried, crushed with a wooden rolling pin, and sieved. All the material except that of a stony nature was worked down to pass a 1-mm. sieve and constituted the sample analyzed. Those samples from which limestone particles were sieved out were tested by (1) the Hopkins potassium nitrate method, (2) the Veitch method using no limewater, and (3) the Veitch method using no limewater and not evaporating on the steam bath. The results are given in Table 1.

TABLE 1.—*Acidity of soils containing limestone, as determined by three methods of testing.*

Sample No.	Depth of sample, inches.	Hopkins method, lime requirement per 3,000,000 pounds of soil.	Veitch method, no limewater added.	
			Evaporated on steam bath	Not evaporated on steam bath
X-28	36 to 41	Alkaline	Alkaline	Alkaline
XI-28	18 to 27	37.5	do.	Acid
	27 to 36	56.4	do.	do.
	36 to 45	150.0	do.	do.
III-51	9 to 18	Alkaline	do.	Alkaline
	18 to 27	56.4	do.	Acid
	27 to 36	75.0	do.	do.
	36 to 45	18.9	do.	do.

The Veitch method is quite generally taken as giving the lime requirement of a soil. The results here reported show that there are reactions taking place in the soil at the steam bath temperature that do not take place when the soil and water mixture is not heated. The Veitch determination gives the reactions between soil, water, and calcium hydroxide at steam bath temperature and does not represent the lime requirement of the soil at ordinary temperature.

[7] Veitch, F. P. Comparison of methods for the estimation of soil acidity. *In* Amer. Chem. Jour., 26: 637–662. 1904.

THE OCCURRENCE OF DWARFNESS IN OATS.[1]

C. W. WARBURTON.

In the course of studies of selections from certain oat varieties grown in head rows on irrigated land at the Aberdeen (Idaho) substation in 1916, one row of Victory oats was found in which 8 of the 20 plants were of an entirely distinct type. While 12 of the 20 were normal plants of the variety, maturing at the usual time and reaching the same height as those in adjoining rows, these 8 plants were simply dense tufts of basal leaves with occasional culms not over 9 inches in height, bearing very small panicles. At the time these plants were found, early August, the normal plants were nearing maturity, while the upper portions of the panicles on the dwarf plants were just emerging from the sheaths. In most cases only 3 or 4 spikelets emerged, tho a few additional ones remained enclosed within the sheaths. These dwarf plants for the most part failed to mature seeds before frost, tho they were watered and protected from injury. The few seeds which were produced were saved, as were also the seeds from the tall plants in the same row. A tall and a dwarf plant from this row are shown in Plate 2, figure 1, while figure 2 shows the entire row.

The few seeds matured by the dwarf plants of the previous year were sown in 1917, and all those which were viable produced dwarf plants exactly like the parents. About 40 seeds from each of 10 of the 12 tall plants were sown in individual plant rows. Of these 10 plants, 4 produced all tall plants and 6 produced both tall and dwarf plants like those in the original row. In all, 168 tall plants and 66 dwarfs were produced, a ratio of 2.55 to 1. Some of the rows, however, showed an exact 3 to 1 ratio.

In 1918, a part of the seed produced in 1917 from the individual tall plants in four of these segregating rows was sown again at Aberdeen. Seed from the dwarfs was also sown, as was some from the rows showing all tall plants the previous year. All of the seed produced by both tall and dwarf plants in one of the segregating rows was sent to Dr. H. H. Love at Cornell University and all from the remaining one to Prof. H. K. Hayes at the Minnesota station.

At Aberdeen, seed from the rows producing all tall plants in 1917

[1] Contribution from the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Published by permission of the Secretary of Agriculture. Received for publication December 17, 1918.

FIG. 1. A dwarf and a tall plant from the original row in which dwarf oats were found.

FIG. 2. The original row of Victory oats in which dwarf plants were found. The green tufts are noticeable at various places in the row.

again produced all tall plants in 1918, and seed from dwarf plants in segregating rows produced dwarf plants, showing that dwarfness in this strain is recessive. Of the 117 tall plants produced in 1917 in 4 segregating rows, 46 produced all tall plants in 1918 and 71 again segregated into tall and dwarf, whereas it was to be expected that 39 would breed true for tallness and 78 would segregate in a ratio of 3 tall to 1 dwarf. The total number of plants produced in these 71 rows was 837, of which 628 were tall and 209 dwarf, an exact 3 to 1 ratio. The detailed figures for each family are shown in Table 1,[2] together with the records from the Cornell and Minnesota stations.

TABLE 1.—*Progeny record of six heterozygous plants produced in 1916 in a head row of oats in which a dwarf form appeared.*[a]

Plant No.	Progeny record in 1917.		Progeny record in 1918 of tall plants of the previous year.			
	Tall.	Dwarf.	Homozygous	Heterozygous.	Progeny record of heterozygous plants.	
					Tall	Dwarf.
1	29	10	8	21	180	73
2	31	10	17	14	125	34
3	30	9	9	21	185	59
4	27	14	12	15	138	43
5	24	14	10	14	326	95
6	27	9	9	18	582	210
Totals......	168	66	65	103	1,536	514

[a] The progeny of plant 5 was grown at Cornell University in 1918 and that of plant 6 at the Minnesota station.

Doctor Love grew the progeny of 24 plants from a single heterozygous row of 1917. Of these 24 plants, 10 proved to be homozogous for tallness, a proponderance of homozygous plants over the expected number of 8 in 24. The 14 heterozygous plants produced 326 tall and 95 dwarf plants, a ratio of 3.43 to 1, showing a preponderance of tall plants. Doctor Love suggests that this "may be due to the fact that the dwarfs are not so hardy and some of them may die out in the very early stages." None of the seeds from dwarf plants of the 1917 crop proved viable, and none of the dwarfs produced from heterozygous tall plants matured seed in 1918 in the open, but some are now being grown in the greenhouse in the hope of producing viable seed there.

Of the family grown at the Minnesota station, Professor Hayes reports that the seed from dwarf plants again produced dwarfs. Of

[2] The writer is indebted to Mr. T. R. Stanton for the data recorded at Aberdeen in 1918.

the 27 tall plants of the 1917 crop, 18 proved to be heterozygous, the exact proportion to be expected if dwarfness is a simple recessive character. The 18 heterozygous tall plants produced 582 tall and 210 dwarf plants in 1918, a ratio of 2.77 tall to 1 dwarf.

Summarizing the results obtained at Aberdeen, Ithaca, and St. Paul, 65 tall plants out of 168 produced in 1917 from 6 families proved to be homozygous for tallness and 103 proved to be heterozygous, a proponderance of homozygous plants, as the expected numbers are 56 and 112. The 103 homozygous plants produced 1,536 tall and 514 dwarf plants, almost an exact ratio of 3 tall to 1 dwarf.

No adequate explanation of the sudden appearance of this dwarf form has yet been found. The plant from which it developed grew in 1915 in the varietal classification nursery at Aberdeen, and for two or three years previous this lot of Victory oats had been grown from bulk seed produced from rows in this nursery. The Victory oat originated as a pure-line selection from a commercial variety, not a hybrid, at the Swedish Seed-Breeding Institute, Svalof, Sweden. The tall plants produced in the original row with the dwarfs in 1916 and those from both homozygous and heterozygous individuals in 1917 and 1918 are in every visible respect normal Victory oats, and there is no evidence that hybridization has entered into the production of this dwarf, tho natural hybrids in oats are not infrequent at Aberdeen.

The writer has not found any record in literature of the occurrence of similar dwarfs in oats nor of exactly parallel cases in other cereals. Early in 1916, however, his attention was called by Prof. G. H. Cutler to the occurrence of dwarf forms in selections of Marquis wheat. This variety is a selection from a hybrid between Red Fife and a dwarf Indian wheat, tho the Indian parent is much less dwarf than the forms found by Cutler and described elsewhere in this issue of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY[3].

Altho dwarf wheats appear to be not uncommon in hybrids produced in Australia, their occurrence in America has not been noted, so far as known, except by Cutler. Richardson[4] reports that of 15,800 plants of hybrid parentage grown at Longerenong in 1912, 28 dwarf or grass-tuft plants appeared, tho there were none among 35,000 plants in straight selection plots. At Rutherglen 45 grass-tuft plants were found in 18,500 cross-bred plants, but none in the regular selections from varieties. The dwarf plants appeared in 12

[3] Cutler, G. H. A dwarf wheat. *In* Jour. Amer. Soc. Agron., 11: 76–78. 1919.

[4] Richardson, A. E. V. Wheat and its cultivation. Victoria Dept. Agr. Bul. 22, p. 115, 116. 1913.

different crosses, of which 6 were crosses with Indian wheats. The average height of the plants was 9 inches. Less than 50 percent formed heads, and only 9 percent produced grain.

The most striking and complete records of dwarf wheat plants, however, are those of Farrer.[5] Tho the reading of Farrer's paper in its entirety is recommended to those who are interested in cereal breeding, it seems well worth while to quote at length from it here, as it may not be available in many libraries. Farrer writes:

For the purpose of getting abundant material to select from, I like to make my crosses between varieties which differ sufficiently in type for their progeny to be highly variable. Now, it is quite common to find amongst the progeny of such crosses, especially in the second and future generations until they have been selected out, plants which are entirely different from ordinary wheat plants. These plants, which can be recognized long before the wheat plants come into ear, have the appearance of compact and generally dense clumps of grass with leaves which are stiffer, narrower, and much more erect than those of ordinary wheat plants. They remind me, in fact, of the young plants of the spelt, *Triticum monococcum*, which I grew one year. Sometimes, but very far from always, and later than the wheat plants in their respective rows, they produce a few—generally only one or two—meagre heads on stalks which scarcely rise out of the clumps of leaves, but many of them usually die off before they are old enough to head. I have never noticed that the heads they bear partake in their appearance of those of the wheat plants from which they have come; indeed, it usually happens that they are much less compact and thinner, as well as smaller than the ears of any variety of wheat. Occasionally, indeed pretty frequently, one of them will be met with which looks as if it was struggling to rise to the dignity of a wheat plant, and its leaves will then lose their characteristic stiffness and narrowness, and it will even succeed in bearing two or three fairly good heads on stalks which have risen a few inches above the clump of leaves. In 1895, I harvested a few ears from grass-clump plants and planted the seeds from them. In one case the plants they produced (about thirty in number) were all grass-clump plants; but in others they were mixtures of grass-clump plants and wheat plants—sometimes the one predominating and sometimes the other. It is usually the second generation of the cross-bred before grass-clump plants appear; after which they continue to show themselves in diminishing numbers for a season or two, when they disappear—are selected out; but they are occasionally produced in the first generation, as is the case the present season with the plants of a cross between the "Bokhara Desert" wheat and a Fife-Indian variety, all of which (four in number) that grew from the seeds I made in crossing, are grass-clump plants. It is seldom that these grass-clump plants result from crosses between varieties which are in general cultivation in Europe and America. . . .

There is one suggestive fact in connection with the occurrence of these grass-clump plants. It is that in general there is a poorer stand than is usual in the drills that contain them, and the poorest in those that have the greatest number

[5] Farrer, William. The making and improvement of Australian wheat. *In* Agr. Gaz. N. S. Wales, 9: 152–156. 1898.

of them. It looks as if the crosses which produce such plants are violent enough for the seeds, which produce them, to be of low germinating power. . . . Grass-clumps plants are produced in the greatest number by first crosses between different types of bread wheat, and appear to be produced by crosses between bread wheats alone; at any rate, the crosses I have made between bread wheat and macaroni wheats, between bread wheat and poulard wheats, and between bread wheats and *Triticum amyleum* have produced none.

While neither the dwarf wheat nor the dwarf oat plants are likely to prove of economic value, they are interesting variations well worth further study. It is the intention, as opportunity offers, to use the dwarf oat plants in inheritance studies with hybrids and also to search carefully for other dwarf forms. If other workers wish to study this dwarf oat, the writer will be glad to furnish a few seeds on request.

A DWARF WHEAT[1]

G. H. CUTLER.

When the writer was professor of cereal husbandry at the University of Saskatchewan, where it was his privilege to plan and inaugurate the cereal crop improvement experiments, an interesting discovery was made. In a plot of commercial Marquis wheat, which had not been specially selected since it was originated and multiplied for distribution, a plant of very low stature appeared—a dwarf wheat. It measured about 9 inches in height, while others of similar origin measured as high as 40 inches.

During the harvest season of 1913 the writer selected typical Marquis heads from plants that in every way appeared normal. In the winter of 1913–14, after reserving sufficient material to sow a foundation plot of one-fiftieth acre, some 200 heads were chosen from the balance to form the basis for special studies in heredity. In making the latter selection special care was exercised to take only typical heads. Each head was then thrashed and the product placed in an envelope. A head row of each consisting of 20 seeds was then sown.

Before harvest it was quite evident that some head rows possessed more variation than was usual. The widest departure from the Marquis type was revealed by head row No. 186, this row including plants ranging from 9 to 40 inches high. Other variable characters present were color of chaff, beardedness, shape of kernel, etc., but these variations were not confined to row No. 186.

[1] Contribution from the University of Alberta, Edmonton (South), Alta. Received for publication January 18, 1919.

In 1915 a head row from each plant was sown. The results at harvest showed that the plants of lowest stature gave rise to a large percentage of low stature plants, in some cases 100 percent, whereas the normal talls produced 100 percent talls and a careful analysis of the intermediates revealed 25 percent dwarfs, thus behaving as a simple Mendelian character. It should also be pointed out that the other variable characters revealed a significant segregation, altho more difficult to differentiate. Beardedness was distinctly Mendelian. The work was again conducted in 1916, when the results again preponderately bore out the fact that the dwarf condition was hereditary. In the winter of 1917 the writer severed his official relations with the University of Saskatchewan to take up a somewhat broader field of work in the University of Alberta and was therefore forced to give up these studies.

Some interesting queries arise regarding this peculiar form:

1. What is the origin of this dwarf? The fact that this form occurs regularly in each generation and is not found in other varieties of wheat growing on similar soil conditions indicates that the cause is not to be looked for in the environment. It cannot be due to lack of nutrition.

2. If hereditary, why should Marquis wheat give rise to it? Richardson[2] states that these forms appeared in twelve different crosses, of which six were crosses with Indian wheats. The average height of the "tufts" was 9 inches. Farrer[3] observed a number of these clumps in his cross bred plots from time to time. He does not state that his low stature forms resulted from Indian wheat crosses, altho it is worthy of note that he made extensive use of such wheats in his breeding work. He does state, however, that these grass-clump plants were produced in the greatest numbers by first crosses between widely different types of bread wheat (*T. sativum*) and appear to be produced by crosses between bread wheats alone.

Marquis wheat is a descendant from an Indian wheat known as Hard Red Calcutta, the other parent being Red Fife, a widely different type of wheat. As this form was discovered frequently in Marquis in 1914, 1915, and 1916, and as dwarfs were found in other varieties of wheat similarly treated, including Red Fife, is it fair to conclude that the origin of this dwarf wheat can be traced to its peculiar Indian ancestor?

[2] Richardson, A. E. V. Wheat and its cultivation. Victoria Dept. Agr. Bul. 22, p. 115, 116. 1913.

[3] Farrer, William. The making and improvement of Australian wheat. *In* Agr. Gaz. N. S. Wales, 9: 152–156. 1898.

3. Is it the result of natural crossing between two different strains of Marquis having a tendency towards dwarfness? Natural crossing has been shown to be not at all unusual among wheats on the experimental plots at Saskatoon; therefore such a process might easily come within the range of probability. No crosses were made to confirm this or query No. 2.

4. All observations seemed to point to the fact that this dwarf condition was a simple dominant to tallness, despite the fact that the original parent was to all intents and purposes a normal tall. Since the original selection was merely a head selection from vigorous plants one cannot be quite certain as to its absolute height, altho the writer feels confident that its height was not noticeably unusual. It is conceivable, however, that it was heterozygous in this particular.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The address list as printed in the December issue contained 509 names. Since that time 7 new members have been added, 1 has been reinstated, and 2 have resigned, making a net gain of 6 and a present membership of 515. The names and addresses of the new members, with such changes of address as have been brought to the attention of the secretary or the editor, are as follows:

New Members.

Fahrnkopf, H. F. T., 216 Agrl. Bldg., Univ. of Ill., Urbana, Ill.
Fuller, F. E., Montana State College, Bozeman, Mont.
Hastings, H. G., H. G. Hastings Co., Atlanta, Ga.
Oldenburg, F. W., College Park, Md.
Smith, Oliver, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Steinmetz, F. H., 2362 Bourne Ave., St. Paul, Minn.
Stoudt, John M., Hershey, Pa.

Member Reinstated.

Carroll, J. S.

Members Resigned.

Carroll, J. S. Foord, J. A.

Changes of Address.

Delwiche, E. J., R. F. D. No. 3, Green Bay, Wis.
Emerson, Paul, University of Idaho, Moscow, Idaho.

GILLIS, M. C., Agr. Expt. Sta., La Fayette, Ind.
HOPKINS, E. S., Olds, Alberta, Canada.
KRAFT, J. S., Bryan, Texas.
MARTIN, JOHN H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
NEWTON, ROBERT, Senneville, Quebec, Canada.
PRIDMORE, J. C., 613 Continental Bank & Trust Bldg., Shreveport, La.
WALTER, E. J., 21 Fifteenth Ave., Columbus, Ohio.

NOTES AND NEWS.

Ross R. Childs, who has been in the aviation section of the military service for the past several months, has now received his discharge and is again with the office of cereal investigations, U. S. Department of Agriculture. At present he is engaged in field work in the Southeastern States, in connection with the extension of rice production.

A. D. Ellison, until recently a lieutenant in the gas defense service, has received his discharge and is now engaged in extension work for the U. S. Department of Agriculture in connection with the increased production of flax in the Southwestern States.

Paul Emerson, for the past year soil bacteriologist of the Maryland station, is now associate biologist at the Idaho station.

S. C. Harmon, instructor in agronomy and associate agronomist of the Virginia station, has resigned to take charge of agricultural work in the high school at Driver, Va. He has been succeeded by F. S. Glassert.

E. R. Lloyd, director of the experiment station and extension service in Mississippi for many years, has resigned to assume the directorship of the Memphis Farm Development Bureau. He has been connected with the Mississippi college and station since 1888. R. S. Wilson, formerly assistant director of extension, succeeds him as director of extension, while J. R. Ricks, formerly vice-director of the experiment station, now becomes station director.

David Lubin, founder of the International Institute of Agriculture at Rome and American member of the board of directors of the institute since its formation, died in Rome January 9 from influenza, at the age of about 78 years. He was formerly a merchant in Sacramento, Cal., but has been intensely interested in agriculture for many years.

John H. Martin, superintendent of the Harney Branch Field Station, Burns, Oregon, for the past year, has resigned to become as-

sistant in wheat investigations with the Federal office of cereal investigations.

Raymond A. Pearson, assistant secretary of agriculture since August, 1917, resigned in October to resume his duties as president of Iowa State College. He was succeeded by George I. Christie, director of extension in Indiana and for several months previous assistant to the secretary of agriculture. Mr. Christie retains his connection with the Indiana extension service.

A J. Pieters and W. A. Wheeler, of the Department of Agriculture, sailed for Europe December 30 to gather information on clover, grass, and vegetable seed stocks and requirements of European countries.

J. E. Readhimer, county agriculturist of Kane Co., Ill., since 1913, is now departmental adviser in soils in the University of Illinois.

H. S. Records has been appointed assistant professor of agronomy and agronomist at the Northwest Experiment Farm, Crookston, Minn.

G L. Schuster, formerly assistant in field crops at Ohio State University, is now vocational agriculturist in the Lancaster (Ohio) high school.

Harry Umberger, county agent leader in Kansas for the past several years, is acting director of extension in that State, succeeding E. C Johnson, resigned to become director of the experiment station and dean of the college of argiculture at Pullman, Wash.

Carl Vrooman, assistant secretary of agriculture since 1914, has resigned because of ill health.

R. C. Wright, formerly engaged in soil fertility investigations in the Bureau of Plant Industry, has been transferred to refrigeration studies in the Bureau of Markets, U. S. Department of Agriculture.

A recent publication of interest to agronomists is *Botanical Abstracts,* the first number of which made its appearance in September. Burton E. Livingston of Johns Hopkins University is editor-in-chief, assisted by an able board of editors on special subjects. The purpose of the publication is stated to be "to supply prompt citations and abstracts of all papers dealing with botanical subjects, wherever published, just as soon as possible after they appear." This journal, which is published by Williams & Wilkins Company, Baltimore, will be issued monthly, making semi-annual volumes of about 300 pages each. The subscription price is $6.00. The first number contains abstracts or citations of 206 papers.

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FIELD TECHNIC IN DETERMINING YIELDS OF EXPERIMENTAL PLOTS BY THE SQUARE YARD METHOD.[1]

A. C. ARNY AND F. H. STEINMETZ.

INTRODUCTION.

In an article (1)[2] giving results of determination of yields by harvesting parts of plots as compared with harvesting the entire areas, the uses of such a method are outlined and the known literature on the subject reviewed.

Two considerations led to the undertaking of more extensive work along this line in 1918. It seemed desirable (*a*) to extend the work over a period of at least two years and (*b*) to secure data on a method which may be used equally well in sampling broadcasted and drilled forages and grains.

After the compilation of the 1918 results for publication, an article by Kiesselbach (4) was called to our attention. Results are given for the determination of yields by harvesting 14 entire thirtieth-acre plots of seven different varieties or strains of winter wheat as compared with the yields secured by the removal of 20 areas 32 by 32 inches from each plot at locations 10 feet from the ends at intervals of 14 feet on alternate sides. The statement is made that, due to the severe winterkilling, the 14 plots varied markedly in stand and yield, and that, therefore, there was a greater variation between the areas removed within any single plot than would normally be expected.

[1] Published with the approval of the Director as paper No. 159 in the Journal series of the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn. Received for publication January 28, 1919.

[2] Figures in parentheses refer to "Literature cited," p. 106.

The conclusion reached is that the yield from 20 systematically distributed areas 32 by 32 inches may be safely substituted for the yield from the plot from which they are taken.

Materials and Methods.

The Division of Soils has in operation at the substations at Waseca, Morris, Crookston, Grand Rapids, and Duluth, and at the central

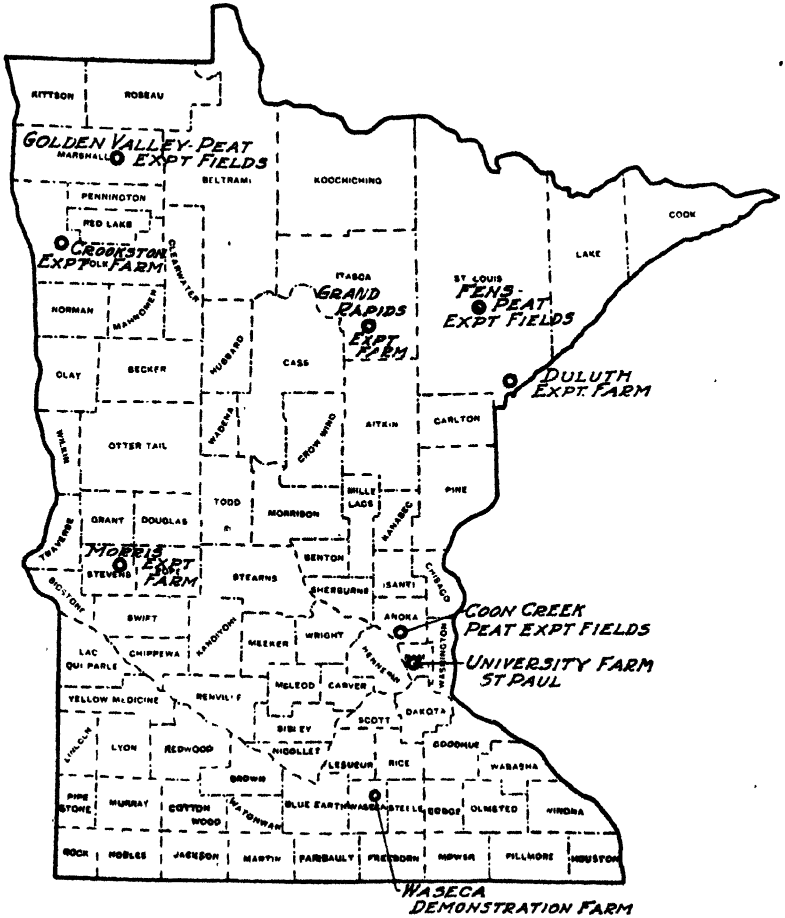

Fig. 7. Outline map of Minnesota showing the location of the experimental tracts. (Courtesy of the Division of Soils.)

station at University Farm, St. Paul, a fertilizer experiment carried out on a uniform plan. The location of the substations and the central station are indicated in figure 7.

Each series on which the experiment is carried out consists of 18 plots 2 rods by 8 rods or one-tenth acre. The plots are separated by 2-foot alleys and the series by roadways either cultivated or seeded to grass. In addition to the check there are five treatments which are designated here as A, B, C, D, and E. The check and each of the five treatments occupy in a series three systematically distributed plots. On each series lime has been applied crosswise to half of each plot. In 1918 there was available for this work 162 tenth-acre plots, located in the State as follows: 18 sown to barley at Waseca; 54 sown to wheat at Morris; 18 sown to oats at Grand Rapids and at Duluth; and 54, of which 18 were sown to winter rye and 36 to wheat, at University Farm, St. Paul.

Ten square yards of the standing grain as indicated in figure 8 were removed from each plot shortly before harvesting the product of the entire plot with the binder. All of the grain was well ripened before the square-yard samples were removed. Five square yards were located on each half of each plot, 1, 2, 3, 9 and 10 on the unlimed and 4, 5, 6, 7, and 8 on the limed half. The square yards were

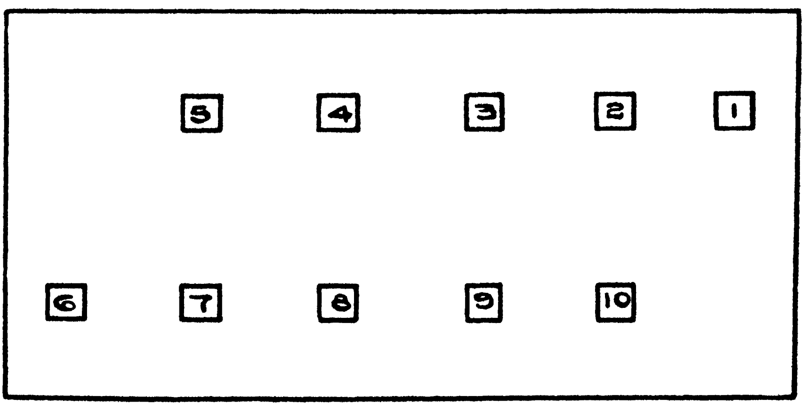

FIG. 8. Outline of tenth-acre plots showing location of square yards removed in determining yields.

located not less than 7 feet within the plot from the sides and ends, thus avoiding places where the drill lapped in seeding and small inequalities in stand which would not affect materially the yield of the entire plot.

The instrument for laying off the square yards shown at A was made of steel 0.75 inch wide and 1.4 inches thick, shaped properly and reinforced at the corners. The fourth side shown at B (fig. 9) was made of oak. No particular difficulty was experienced in obtain-

ing the desired square yards accurately with this instrument. However, in all probability, a better instrument can be devised than the one used.

As the square yards of grain were removed each one was tagged. They were then carried out and the heads or panicles with approximately one-third of the straw from each square yard cut off with a cornknife having a serrated blade and placed separately in flour bags. At the substations the flour bags containing the unthrashed grain were put into large jute bags and shipped to University Farm. The bags containing the unthrashed grain were hung under the broad cornices of a building to dry. After being dried thoroly, the grain was beaten out by hand and the straw and chaff separated by passing through a fanning mill. The grain from the square yards may have been somewhat lower or higher in moisture content at the time it was weighed than the product of the entire plot when it was weighed. This would tend to lower or raise the yields from the square yards slightly as compared with the yields from the entire plots. The weight of the grain removed from each plot in the 10 square yards was added to that harvested by the binder to determine the yield of the entire plot.

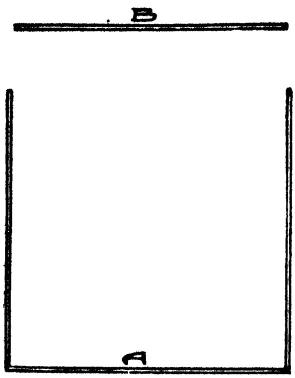

FIG. 9. Instrument used in laying off the square yard.

METHOD OF DETERMINING YIELD FROM THE SQUARE YARDS.

The yield of the grain in grams was determined for each square yard in order that the various combinations could be made for the comparison with the yield secured by harvesting the entire tenth-acre plot. In actual practice all the yards removed from any one plot would be combined at harvest and only one determination of yield made for each plot.

The combinations of the square yards for the comparison with the yields ascertained by the harvesting of the entire tenth-acre plots were made as follows. For the determination by 10 square yards the yields of the 10 were added and the bushels per acre were calculated. For the determination by 9 square yards, the yields of square yards 1 to 9 inclusive were totaled and the bushels per acre calculated; for

8 square yards, 2, 3, 4, 5, 7, 8, 9, and 10; and for 5 square yards, numbers 2, 3, 4, 8, and 9 were used. For the determinations by 4 square yards at the ends and 4 square yards at the center respectively, the yields of 2, 5, 7, and 10 and 3, 4, 8, and 9 were totaled and the yield in bushels per acre calculated.

METHOD OF DERIVING PROBABLE ERROR.

The method of arriving at the probable error for a single determination for the yields from the tenth-acre plots and for the square yards is that employed by Wood and Stratton (7). This method of working probable errors is illustrated and used in presenting the data obtained in 1917 (1). For the convenience of the reader the explanation of the method is repeated. It is briefly as follows: The yields of each consecutive pair of plots receiving the same treatment are averaged and the deviation from the mean of each pair ascertained. Each deviation is then calculated to a percentage of the mean yield of the pair. After the deviation in percentage of the mean yield of each pair is ascertained, the arithmetical mean of the total number of percentage deviations is calculated. This gives the probable error in percentage of the mean for a single determination. In deriving the probable error in percentage of the mean squared, the deviation in percentage of the mean of each pair is squared, the arithmetical mean taken, and the square root of the result extracted.

The procedure in deriving the probable error by the pairing method is illustrated by using the yields of the three check tenth-acre plots on Series II at the Morris substation, as is shown in Table 1.

TABLE 1.—*Example showing method of deriving probable error by the pairing method.*

Plot No.	Yield in bushels per acre.	Average yield in bushels per acre of pairs of similarly treated plots.	Deviation in bushels per acre from the mean yields of the pairs.	Deviation in percentage of the means of each pair.	Deviation in percentage of the means of each pair squared.
1	18.2	18.0	0.2	1.1	1.2
7	17.7	16.7	1.0	5.9	34.8
13	15.7				

The probable errors for single determinations derived from the 106 pairs of tenth-acre plots and from the 1,073 pairs of square-yard areas are given in Table 2.

Comparison of the Probable Error for Single Determinations of the Yields from Tenth-Acre Plots and from Square Yard Areas Removed from Them.

As is indicated in Table 2, the probable errors in percentage of the mean yields for single determinations ascertained by harvesting entire tenth-acre plots and square-yard areas from those plots varied considerably according to location.

TABLE 2.—*Mean probable error for yields from the tenth-acre plots and from the square yards removed from tenth-acre plots ascertained by the pairing method (a) in the percentage of the mean yield of each pair and (b) in the percentage of mean yield of each pair squared.*

TENTH-ACRE PLOTS.

Source.	Location	Number of plots.	Number of pairs.	Probable error in percentage of mean.	Probable error in percentage of the mean squared.
Wheat	Morris substation	54	36	3.85	4.86
Wheat.	University Farm	36	24	4.70	5.45
Barley	Waseca substation.	17	11	5.50	6.93
Rye.	University Farm	18	12	3.10	4.35
Oats.	Duluth substation	17	11	4.70	6.54
All tenth-acres except oats at Grand Rapids substation	. . .	142	94	4.27	5.45
Oats .	Grand Rapids substation	18	12	9.13	11.14
All tenth-acre plots	. . . . .	160	106	4.82	6.35
SQUARE YARDS REMOVED FROM PLOT.					
Wheat	Morris substation.	540	358	8.52	11.00
Wheat	University Farm	359	236	8.36	10.72
Barley	Waseca substation.	180	120	8.29	10.52
Wheat and barley	.	1,079	714	8.56	10.82
Rye	University Farm	180	120	11.51	15.59
Oats . .	Duluth substation	179	119	13.09	16.01
Rye and oats	. . . . .	359	239	12.29	15.80
Oats	Grand Rapids substation	180	120	27.50	33.00
All square yards .		1,618	1,073	11.52	13.75

For the yields from the tenth-acre plots the probable error in percentage of the mean for single determinations varied from 3.10 for the rye at University Farm to 9.13 for the oats at Grand Rapids; and, when the results from all of the tenth-acre plots are considered, the probable error in percentage of the mean yields for single determinations is 4.82.

The probable error in percentage of the mean yield for single determinations on the square-yard areas vary from 8.29 for the barley at Waseca to 33.00 for the oats at Grand Rapids. When the yields of all of the square yard areas are considered, the probable error is

11.52. The oats on a strip running diagonally across several of the plots at Grand Rapids were very much shorter than those in other portions of the plots. This accounts largely for the wide variation in the yields of the square yards at that location.

The probable error in percentage of the mean for single determinations, 4.82, where the entire tenth-acre plots were harvested, is very similar to the 5 percent given by Wood and Stratton (7) for plots one-eightieth acre in size or larger and the 5.35 percent reported by Arny and Garber for tenth-acre plots (1). For the square yards, which are $\frac{1}{4840}$ acre in size, the probable error in percentage of the mean, 11.52, when the total number is considered, is practically identical with the 12 percent given by Wood and Stratton (7) for areas of this size and somewhat greater than the 9.98 percent reported by Arny and Garber (1) for plots $\frac{1}{5280}$ acre in size.

Comparison of the probable errors in percentage of the mean and probable errors in percentage of the mean squared as given in columns 5 and 6 of Table 2 show the latter to be the greater in each instance. As the probable errors in percentage of the means squared are the greater, they are used as the more conservative basis on which to base the discussion of the results.

TABLE 3.—*Probable error in percentage of the mean squared for a single determination, for three determinations of yield from tenth-acre plots and from one square yard removed from tenth-acre plots, and for 10, 9, 8, 5, and 4 square yards removed from three tenth-acre plots of similar treatment.*

RESULTS FOR 1918.

Source	Number of pairs.	For single determinations.	For 3 determinations on plots of similar treatment.	For given number of determinations by removal of square yards from 3 plots of similar treatment.				
				10.	9.	8.	5.	4.
Tenth-acre plots:								
For all crops at all locations	106	6.35	3.67					
For oats at Grand Rapids	12	11.14	6.44					
Square-yard areas:								
For all crops at all locations	1,073	13.75	7.95	2.52	2.65	2.81	3.55	3.98
For rye at St. Paul and oats at Duluth	240	15.80	9.13	2.89	3.04	3.23	4.08	4.57
For oats at Grand Rapids	120	33.00	19.07	6.03	6.36	6.74	8.52	9.54

RESULTS FOR 1917.

Source	Number of pairs.	For single determinations.	For 3 determinations on plots of similar treatment.	10.	9.	8.	5.	4.
Tenth-acre plots:								
For all crops at all locations	168	7.12	4.12					
For oats at Duluth	12	14.74	8.51					
Square-yard areas:								
For all crops at all locations	432	12.93	7.47		2.49		3.34	3.79
For oats at Duluth	108	16.83	9.72		3.24		4.35	4.86

In Table 3 are summarized the probable errors in percentage of the mean squared for the tenth-acre plots and for the square yards in 1918, and for convenience the probable errors determined in 1917 are also given.

Examining first the probable errors for single determinations as given in column 3 of Table 3, it is seen that in 1918 the error for single determinations on tenth-acre plots is half that on square-yard areas when all the plots are considered. The number of determinations in each case is sufficiently large to give reliable results. For single determinations on tenth-acre plots at Grand Rapids, the probable error is 11.14 percent, which approximates the 13.75 percent for the square-yard areas at all locations. The probable error for single determinations on square-yard areas at Grand Rapids is 33 percent, which is more than twice as great as the probable error for yields on square-yard areas at all locations.

In 1917 the probable error for single determinations of yield on tenth-acre plots, considering all locations, was 7.12 percent. For yields on square-yard areas the probable error for single determinations was 12.93 percent, or nearly twice as great as that for single determinations on tenth-acre plots. At Duluth single determinations on tenth-acre plots gave a probable error somewhat greater than that for square-yard areas, all locations considered. For the determination of probable error for the tenth-acre plots at Grand Rapids in 1918 and at Duluth in 1917 the numbers are scarcely large enough to be certain that the results are reliable.

Having noted that the probable error for single determinations of yield on tenth-acre plots was in 1917 and 1918 approximately half that for single determinations on square-yard areas, it is obvious that equal increases in the number of the determinations on these two sizes of plots will reduce the error in approximately the same ratio. Knowing the probable error for single determinations for yield on tenth-acre and square-yard plots, the probable error for any given number of determinations for the same treatment may be derived by using the formula

$\dfrac{\text{probable error for single determination}}{\sqrt{\text{number of determinations}}}$. Examination of the probable errors for three determinations of yield on tenth-acre plots and on square-yard areas as given in the fourth column of Table 3 shows that they bear the same relation as in column 3, where the probable error is for one determination.

It has been noted that the probable errors for single determinations

of yield on tenth-acre plots in 1918 and 1917 are approximately half those for single determinations on systematically distributed square-yard areas. Using the formula given above in deriving the probable error for any given number of determinations, it is evident that the use of four systematically distributed square-yard areas should reduce the probable error for square-yard areas to approximately that for single determinations on tenth-acre plots. Comparison of the probable error considering all the locations for three determinations of yield on tenth-acre plots with that for 4 square-yard areas removed from the same tenth-acre plots as given in columns 4 and 9 of Table 3 indicates that this is approximately the case in both 1918 and 1917. Likewise, 5 square yards removed from 3 tenth-acre plots of like treatment gave probable errors approximately equal to or somewhat less than those for the 3 tenth-acre plots. Considering the results from all tenth-acre plots and all square yards, 8 and 9 square-yard areas in 1918 and 9 in 1917 systematically removed from 3 tenth-acre plots gave probable errors considerably lower than that for 3 determinations on tenth-acre plots, and 10 square yards in 1918 gave a probable error approximately two-thirds that of the 3 tenth-acre plots from which they were removed.

For the rye at St. Paul and the oats at Duluth in 1918 and for the oats at Duluth in 1917 from 5 to 8 systematically distributed square-yard areas appear necessary to reduce the probable error to approximately that of single determinations on tenth-acre plots.

At Grand Rapids in 1918 yield determinations from 9 systematically distributed square-yard areas removed from 3 tenth-acre plots were necessary to reduce the probable error to approximately that for 3 tenth-acre plots.

It is important to note in this connection that systematic distribution of the small areas is necessary to secure the desired reduction in the probable error from single determinations; also, that the probable error for any number of determinations is based on the probable error for single determinations. If the probable error for a single determination in any test is low, then the probable error for any number of determinations will be relatively low also.

From the results for the two years the following conclusions may be drawn:

From relatively uniform standing grain 4 to 5 systematically distributed square-yard areas removed from tenth-acre plots gave approximately the same probable error for yield as harvesting the products of entire plots; and the probable error for the yield from 10

square-yard areas removed from tenth-acre plots was approximately two-thirds that for the tenth-acre plots from which the square yards were removed.

Where the stands of grain were relatively nonuniform 5 to 10 systematically distributed square-yard areas were necessary to reduce the probable errors to approximately equal those for the yields from the tenth-acre plots from which the square-yard areas were removed.

These results are strictly applicable for the seasons of 1918 and 1917 to the plots on the series mentioned. It appears, however, that where determinations are sufficiently large in number and are made covering varying conditions of soil and climate probable errors for areas of given size are very similar.

Comparison of Increases in Yield from Different Treatments as Ascertained by the Tenth-Acre Plot and the Square-Yard Methods.

The probable errors for determinations of yield are of prime importance in differentiating between fluctuations due to soil heterogeneity and other disturbing factors and the results due to the variable in the experiment.

The odds are 30:1 against a difference 3.81 times its probable error in one direction only being due to normal variation (7).

Multiplying the probable errors for three determinations on tenth-acre plots and for 10, 9, 8, 5, and 4 determinations on square-yard areas removed from 3 tenth-acre plots by 3.81 gives the probable least significant difference in yield expressed in percent between any two treatments. These differences are given in Table 4.

Table 4.—*Increase in yield expressed in percentages due to fertilizer treatment which may be considered significant.*

Source	Three tenth-acre plots of same treatment.	Square yards removed from each three plots of same treatment.				
		10.	9.	8.	5.	4.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Tenth-acre plots:						
All tenth-acre plots	13.98					
Plots at Grand Rapids	24.54					
Square-yard areas:						
All square yards		9.60	10.09	10.70	13.05	15.16
Rye at University Farm and oats at Duluth		11.01	11.58	12.31	15.54	17.04
Oats at Grand Rapids		22.97	24.23	25.68	32.46	36.35

For the tenth-acre plots at all locations except Grand Rapids and for 4 square yards at all locations the least differences in yield ex-

pressed in percentage which may be considered significant are 13.98 and 15.16 percent respectively. For determinations from 10 square yards removed from each of 3 tenth-acre plots, 30 determinations in all, a difference between the yields of any two treatments of 9.60 percent appears to be significant. For the yield determination from the square yards removed from 3 tenth-acre plots of rye at St. Paul and oats at Duluth the significant differences are somewhat higher than where the yields from all square yards is considered. For the oats at Grand Rapids a difference of 24.54 percent between the yields from any two treatments on 3 tenth-acre plots and a difference of 36.35 percent between any two treatments as determined from 4 square yards removed from 3 tenth-acre plots appear to be necessary in order to be reasonably certain that the increases are due to treatment.

The increases in yield expressed in percentage over the check as determined from 3 tenth-acre plots and from 10, 9, 8, 5, and 4 square yards removed from each of 3 tenth-acre plots are given in Tables 5 to 9 inclusive. The results for the determinations at each location are discussed separately for the reason that the soil at each point is more or less different.

RESULTS WITH WHEAT AT THE MORRIS SUBSTATION.

The increases in yield of wheat at the Morris substation due to fertilizer treatment expressed in percentage are given in Table 5.

TABLE 5.—*Comparison of the percentage increase in yields of wheat for each fertilizer treatment based on the mean yield of the check plots of Series II, III and IV at the Morris substation.*

Treatment.	Increase percentages in yields as determined by harvesting—						
	Three entire tenth-acre plots	Stated number of square yards from each of three similarly treated tenth-acre plots					
		10	9.	8.	5.	4 at center.	4 at ends.
Series II:							
A	4.65	3.26	1.95	3.28	— —	——	7.89
B	19.81	34.64	34.41	35.53	37.66	44.74	26.97
C	19.76	39.22	38.90	33.00	41.56	43.42	36.17
D	28.48	37.26	39.61	38.82	38.31	43.42	31.57
E	25.00	27.45	27.92	26.32	22.08	23.68	29.60
Series III:							
A	7.74	8.26	5.65	10.13	14.10	13.79	6.61
B	16.83	17.30	15.32	17.72	17.94	18.10	17.36
C	19.86	18.18	15.32	21.94	23.93	22.84	21.49
D	31.65	33.06	29.84	34.60	32.48	31.47	38.02
E	29.29	26.45	21.37	28.69	26.90	24.56	33.06
Series IV:							
A	1.10	11.98	13.23	11.98	12.83	15.38	11.00
B	6.13	29.68	29.63	28.65	27.69	29.67	29.50
C	5.75	17.71	20.11	17.58	20.32	22.53	14.50
D	15.33	26.04	25.90	25.52	29.40	28.02	24.00
E	7.66	16.67	18.52	16.67	22.99	21.98	13.50

Employing 13.98 percent as the least increase in yield over the check which may be considered significant, for the determinations from the tenth-acre plots all treatments except A may be considered as distinctly beneficial on Series II. Using 9.60, 10.09, 10.70, 13.05 and 15.16 as the least increases in yield expressed in percentages as ascertained by removing 10, 9, 8, 5, and 4 square yards respectively from 3 tenth-acre plots, the results are practically the same as were secured from harvesting the entire plots. The percentage increases over that of the check, except for treatment E, are somewhat higher by the square yard than by the entire plot method.

On Series III as on Series II each treatment, except treatment A, was effective by each of the two methods of determining yields. On each of the two series the yields from 4 square-yard areas removed from 3 tenth-acre plots indicated increases in yield due to treatments as effectively as the yields from the tenth-acre plots. On Series III treatments D and E may be considered to be superior to treatments A, B, and C. This is also broadly indicated by the yields from the 10, 9, 8, and 4 square yards at the ends.

On Series IV the yields from the entire plots indicate only treatment D as effective. The yield from the square yards except the 4 at the ends indicate significant increases for all treatments. As indicated by lower probable errors, the yields from the 10, 9, 8, and 5 square-yard areas removed from 3 tenth-acre plots may be considered more accurate than the yields from the 3 tenth-acre plots from which they were taken. This interpretation is supported by the fact that in 1917 (1) treatments B, C, and D were effective by the yields from the 3 tenth-acre plots; treatments B, C, D, and E from the yields from the 9 and 5 square yards; and treatments D and E by the yields from the 4 square yards removed from 3 tenth-acre plots.

Treatments B, C, D, and E may be considered as giving significant increases in yield at Morris.

RESULTS WITH WHEAT AND RYE AT UNIVERSITY FARM.

The increases in yield over the check expressed in percentage for the wheat and rye at University Farm are given in Table 6.

On Series IV none of the treatments appear to have produced significant increases in yield as ascertained from the tenth-acre plots. The yields from the square yards uniformly indicate increases in yield for treatments B, C, and D over the check. For the yields from the 10, 5, and 8 square yards removed from 3 tenth-acre plots, significant increases in yield are indicated for treatments B, C, and D over treatments A and E.

On Series V, the yields from the entire plots do not indicate significant increases in yield for any of the treatments. For treatments B, C, and D significant increases in yield are indicated from the 10 and 9 square yards and for treatments C and D by each number of square yards removed from 3 tenth-acre plots.

TABLE 6.—*Comparison of the percentage increase in yields of wheat for each fertilizer treatment based on the mean yield of the check plots on Series IV and V and of rye on Series VII, University Farm, St. Paul.*

Treatment.	Increase percentages in yields as determined by harvesting—						
	Three entire tenth-acre plots.	Stated number of square yards from each of three similarly treated tenth-acre plots.					
		10.	9.	8.	5.	4 at center.	4 at ends.
Wheat on Series IV:							
A	4.95	4.48	6.82	3.82	7.34	6.11	0.80
B	11.73	18.28	18.93	22.14	24.32	23.28	20.91
C	10.80	18.65	19.32	22.14	21.62	21.00	22.81
D	9.88	18.28	19.32	19.46	20.46	18.70	19.39
E	2.78	4.85	7.58	7.25	8.88	6.11	7.98
Wheat on Series V:							
A	0.82	——	.61	——	——	——	——
B	8.71	10.87	11.66	9.00	10.45	7.12	13.25
C	4.90	18.13	20.85	10.57	18.80	18.60	16.87
D	8.99	15.70	16.87	13.61	14.53	13.95	16.00
E	4.63	5.14	5.83	1.80	.90	——	——
Rye on Series VII:							
A	13.57	11.65	12.26	13.71	15.35	19.37	——
B	38.91	31.07	32.84	34.35	35.15	36.14	22.38
C	34.39	28.64	28.43	36.55	29.21	30.69	31.43
D	34.84	40.29	41.67	48.73	41.09	43.56	41.43
E	28.50	33.50	34.80	38.07	34.16	35.64	29.05

The increases due to treatment on one series confirm that on the other, and support the conclusion that significant increases in yield were secured due to treatment which were not indicated by the yields from the entire tenth-acre plots.

Using the percentage increases indicated in Table 4 for the rye on Series VII, it is evident that all treatments gave significantly increased yields as indicated both by harvesting the entire plots and by removing square-yard areas from them except in the case of the 4 square yards at the ends which do not indicate treatment A as being effective.

The indications are that treatments B, C, D, and E are more effective than treatment A by both methods. The increases in yields from the 10, 9, and 8 square yards indicate that treatment D is more effective than treatment C.

For the rye, significant increases were indicated for all treatments

by both methods. By the removal of 10, 9, and 8 square yards from the 3 tenth-acre plots of the same treatment, it is possible to determine in this case which of the treatments is the best. This difference is not indicated by the yields from the entire plots.

RESULTS WITH BARLEY AT WASECA.

The percentage increases for various treatments applied to barley at Waseca are given in Table 7.

TABLE 7.—*Comparison of the percentage increase in yields of barley for each fertilizer treatment based on the mean yield of the check plots at Waseca substation.*

Treatment	Increase percentages in yields as determined by harvesting—						
	Three entire tenth-acre plots.	Stated number of square yards from each of the three similarly treated tenth-acre plots					
		10	9.	8.	5.	4 at center.	4 at ends
A	11.38	6.29	2.70	7.28	6.60	12.42	1.61
B	15.87	12.26	7.81	12.97	11.64	11.49	14.47
C	8.68	8.18	3.90	8.00	7.55	3.11	12 86
D	11.37	10.38	7.21	10.76	9.75	13.04	7.72
E	——	——	——	——	——	——	——

Significant increase in yield due to treatment is indicated for treatment B only by the entire plot method. The yields from the 10 and 8 square yards indicate treatments B and D as effective. The yields from the 9 square yards removed from each of 3 tenth-acre plots do not indicate any of the treatments as effective.

It may be concluded that on the barley at Waseca, treatments B and D were effective, only the former being indicated as superior to the check by the yields from the entire plots.

RESULTS WITH OATS AT DULUTH.

In Table 8 are given the increases in yield of oats at Duluth over the check by the two methods.

TABLE 8.—*Comparison of the percentage increases in yields of oats for each fertilizer treatment based on the mean yield of the check plots at the Duluth substation.*

Treatment.	Increase percentages in yields as determined by harvesting—						
	Three entire tenth-acre plots.	Stated number of square yards from each of the three similarly treated tenth-acre plots.					
		10.	9.	8.	5.	4 at center.	4 at ends.
A	——	13.38	9.62	13.53	15.18	13.02	14.45
B	4.19	14.37	11.92	16.67	22.67	24.06	9.57
C	——	16.73	15.19	16.86	24.90	20.51	13.67
D	10.40	22.05	15.77	22.75	23.68	18.74	27.15
E	3.64	17.32	13.85	10.59	19.80	21.89	11.33

Employing the percentage increases which seem necessary for significant effect of treatment at this location as given in Table 4, examination of the increases in yield as indicated by the entire plots shows an approach to significant effect for treatment D only.

From the square yards removed from each of 3 tenth-acre plots, 10 indicate significant increases due to each treatment; 9, 5, and 4 at the center indicate all but treatment A as effective; and 8, all but treatment E as effective.

The results from the square yards in 1918 confirm very closely the results obtained by the rod-row method at this location in 1917. The conclusion is obvious that the 10, 9, 8, and 5 square yards removed from each of 3 similarly treated tenth-acre plots indicated significant increases not shown by the yields from the tenth-acre plots.

RESULTS WITH OATS AT GRAND RAPIDS.

The increases in yield of oats at Grand Rapids are given in Table 9.

TABLE 9.—*Comparison of the percentage increases in yields of oats for each fertilizer treatment based on the mean yield of the check plots at the Grand Rapids substation.*

Treatment.	Increase percentages in yields as determined by harvesting—						
	Three entire tenth-acre plots.	Stated number of square yards from each of the three similarly treated tenth-acre plots.					
		10	9	8	5	4 at center.	4 at ends.
A	——	6.71	1.68	11.22	6.31	13.47	9.57
B	25.00	11.26	8.89	10.49	——	11.17	10.00
C	28.80	37.37	38.22	36.00	28.60	58.74	19.57
D	40.80	17.72	17.30	14.39	14.95	33.60	.60
E	——	7.19	——		——	6.34	——

Using for the yields from the entire plots 24.54 as given in Table 4 as the least percentage difference which is probably significant, the indications are that treatments B, C, and D were effective.

Employing for the square yards the least percentage differences which are probably significant as given in Table 4 for the work at this location, treatment C appears to have been effective by the yields from all combinations of square yards except the 4 at the ends.

Due to the unevenness of the stand of the oats on the plots at this location, it was difficult to secure representative samples and the variability of the yields of the square yard areas was abnormally high.

From the nature of treatments B, C, and D it is logical to expect that if one gives a significant increase in yield the other two will also.

Therefore, it may be concluded that 3 similarly treated tenth-acre plots were more efficient in indicating significant increases in yield at this location than 10 square yards removed from these plots.

It appears fair to conclude that where the stands of crop are fairly uniform yields determined from 4 or 5 systematically distributed square-yard areas gives as accurate determinations of yield as harvesting the tenth-acre plots from which the square-yard areas are taken. As probable errors for single determinations usually increase, under similar conditions, with the reduction in size of the plots, 4 or 5 square-yard areas removed from plots less than one-tenth acre in size of relatively uniform crop can be substituted for the yields of the plots from which they are taken with still greater confidence than in the case of tenth-acre plots.

Where the stands of the crop are relatively nonuniform due to variations in soil or water supply, the yields from 5 to 8 square-yard areas systematically distributed may be substituted safely for the yields from plots one-tenth acre in size or smaller.

On plots or fields where stands are very nonuniform due to winter-killing or to marked differences in soil or water supply, the yield from 10 square-yard areas removed from tenth-acre plots may not be sufficiently accurate to substitute for the yield of the plots from which they were taken.

Comparison of the Yields Secured from Tenth-Acre Plots and from Square Yard Areas Removed from Them.

The yield from each tenth-acre plot and from the various combinations of square-yard areas removed from it are of interest chiefly from the standpoint of the technic of conducting plot tests. The yields of each three plots of any treatment with the mean as ascertained by the two methods are grouped in Tables 10, 11, and 12.

Border Effect on Yields.

Plots having alleys on the sides and separated by cultivated roadways on the ends give higher yields than are secured from plots of the same size but not subject to border effect (2).

All plots from which yields are given, except those at Grand Rapids, were separated by alleys on the sides and by roadways either cultivated or in grass on the ends. No borders were removed from the plots separated by alleys. Therefore, except at Grand Rapids where the yields ascertained by the two methods may be expected to be approximately equal, the yields from the entire tenth-acre plot should ordinarily be approximately 5 to 10 percent higher than the yields

TABLE 10.—*Comparison of yields of Marquis wheat grown at the Morris substation under six different treatments as determined from triplicate tenth-acre plots and from 10, 9, 8, 5 and 4 square yards removed from triplicate tenth-acre plots.*

SERIES II.

Source.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.	Treatment	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acre	Check	18.2	17.7	15.7	17.2±0.42	C	20.9	21.9	18.9	20.6±0.49
10 sq. yds.		15.1	15.3	15.4	15.3±0.06		23.7	18.8	21.4	21.3±0.78
9 sq. yds.		15.1	15.4	15.6	15.4±0.08		23.8	19.0	21.5	21.4±0.76
8 sq. yds.		14.3	16.0	15.3	15.2±0.27		23.4	18.3	22.0	21.2±0.84
5 sq. yds.		14.1	16.7	15.3	15.4±0.41		25.1	19.0	21.3	21.8±0.98
4 at cen.		14.2	16.4	15.0	15.2±0.35		24.0	19.3	22.0	21.8±0.75
4 at ends		14.3	15.7	15.5	15.2±0.23		22.9	17.2	22.1	20.7±0.98
Tenth acre	A	17.5	19.8	16.7	18.0±0.51	D	22.9	23.3	20.0	22.1±0.57
10 sq. yds.		14.2	16.4	16.8	15.8±0.45		19.1	25.9	18.0	21.0±1.36
9 sq. yds.		13.7	16.4	17.0	15.7±0.56		19.4	26.2	18.8	21.5±1.31
8 sq. yds.		14.2	16.0	16.9	15.7±0.44		18.7	26.5	17.4	20.9±1.57
5 sq. yds.		13.1	15.7	16.6	15.1±0.58		19.5	26.6	17.9	21.3±1.47
4 at cen.		12.3	16.0	16.8	15.0±0.87		19.5	27.1	18.8	21.8±1.46
4 at ends		16.2	16.1	16.9	16.4±0.16		17.9	25.9	16.2	20.0±1.65
Tenth acre	B	19.1	23.5	18.9	20.5±0.83	E	22.5	21.1	20.9	21.5±0.27
10 sq. yds.		20.0	22.7	19.1	20.6±0.60		20.1	19.1	19.2	19.5±0.16
9 sq. yds.		19.6	22.8	19.8	20.7±0.57		20.3	19.4	19.4	19.7±0.16
8 sq. yds.		19.6	23.2	19.1	20.6±0.71		20.3	18.4	19.0	19.2±0.31
5 sq. yds.		20.2	23.6	19.9	21.2±0.65		20.0	18.2	18.3	18.8±0.31
4 at cen.		20.6	24.0	21.4	22.0±0.57		19.9	17.8	18.6	18.8±0.35
4 at ends		18.6	22.3	16.9	19.3±0.88		20.7	19.0	19.4	19.7±0.27

SERIES III.

Source.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.	Treatment	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acre	Check	27.8	30.5	30.9	29.7±0.54	C	34.4	37.3	35.1	35.6±0.48
10 sq. yds.		22.9	22.5	27.1	24.2±0.81		29.6	29.0	27.3	28.6±0.39
9 sq. yds.		22.9	23.0	28.6	24.8±1.04		29.4	29.3	27.2	28.6±0.39
8 sq. yds.		22.3	22.1	26.8	23.7±0.85		29.3	29.9	27.6	28.9±0.39
5 sq. yds.		22.3	20.7	27.1	23.4±1.06		30.1	29.9	27.0	29.0±0.55
4 at cen.		22.1	20.6	26.9	23.2±1.05		29.6	30.0	25.9	28.5±0.72
4 at ends		22.5	23.5	26.7	24.2±0.70		28.9	29.9	29.3	29.4±0.16
Tenth acre	A	30.9	33.0	32.0	32.0±0.35	D	40.0	39.5	37.8	39.1±0.35
10 sq. yds.		26.5	26.4	25.6	26.2±0.16		31.3	33.8	31.5	32.2±0.44
9 sq. yds.		26.3	26.7	25.6	26.2±0.19		31.6	33.7	31.2	32.2±0.43
8 sq. yds.		26.7	26.6	25.0	26.1±0.31		31.6	33.0	31.1	31.9±0.31
5 sq. yds.		27.0	26.2	26.8	26.7±0.12		31.2	31.2	30.5	31.0±0.12
4 at cen.		28.3	25.5	25.5	26.4±0.51		31.5	30.8	29.2	30.5±0.39
4 at ends		25.1	27.8	24.5	25.8±0.56		31.8	35.3	33.1	33.4±0.54
Tenth acre		33.9	35.6	34.6	34.7±0.27	E	37.8	38.2	39.1	38.4±0.20
10 sq. yds.	B	27.2	28.7	29.3	28.4±0.35		28.0	32.8	30.9	30.6±0.77
9 sq. yds.		27.1	28.8	29.8	28.6±0.43		27.6	32.3	30.5	30.1±0.76
8 sq. yds.		27.0	28.8	27.8	27.9±0.27		27.8	32.9	30.9	30.5±0.82
5 sq. yds.		26.4	28.7	27.7	27.6±0.35		27.6	32.1	29.4	29.7±0.72
4 at cen.		26.0	28.6	27.5	27.4±0.44		26.3	31.4	29.0	28.9±0.81
4 at ends		28.2	29.0	28.1	28.4±0.16		29.3	34.4	32.9	32.2±0.83

TABLE 10.—*Comparison of yields of Marquis wheat*—Continued.

SERIES IV.

Source.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acres	Check	24.7	25.2	28.3	26.1±0.62	C	26.0	26.2	30.5	27.6±0.81
10 sq. yds.		18.8	18.1	20.8	19.2±0.44		22.5	18.6	26.6	22.6±1.46
9 sq. yds.		18.6	17.7	20.4	18.9±0.44		22.3	19.0	26.7	22.7±1.23
8 sq. yds.		18.6	18.0	20.9	19.2±0.49		22.6	18.2	26.9	22.6±1.38
5 sq. yds.		18.3	17.2	20.5	18.7±0.53		21.6	18.7	27.2	22.5±1.38
4 at cen.		18.3	17.1	19.2	18.2±0.35		21.7	18.2	27.1	22.3±1.43
4 at ends		18.8	18.8	22.5	20.0±0.68		23.6	18.3	26.8	22.9±1.37
Tenth acres	A	25.2	25.3	28.7	26.4±0.64	D	30.5	27.6	32.2	30.1±0.74
10 sq. yds.		18.2	20.4	25.8	21.5±1.24		23.5	23.5	25.7	24.2±0.70
9 sq. yds.		18.3	20.2	25.6	21.4±1.20		23.0	23.0	25.3	23.8±0.44
8 sq. yds.		18.1	20.8	25.7	21.5±1.23		22.9	23.0	26.4	24.1±0.64
5 sq. yds.		16.9	19.9	26.6	21.1±1.58		22.6	22.6	27.3	24.2±0.87
4 at cen.		18.0	19.6	25.3	21.0±1.22		22.1	20.9	26.8	23.3±0.99
4 at ends		18.5	22.1	26.0	22.2±1.19		23.7	24.6	26.0	24.8±0.35
Tenth acres	B	25.8	28.0	29.4	27.7±0.58	E	27.9	24.9	31.5	28.1±1.05
10 sq. yds.		22.1	24.8	27.8	24.9±0.91		21.1	21.5	24.5	22.4±0.59
9 sq. yds.		21.9	24.7	26.9	24.5±0.80		21.1	21.4	24.7	22.4±0.64
8 sq. yds.		21.8	24.9	27.5	24.7±0.91		21.3	21.5	24.5	22.4±0.57
5 sq. yds.		20.6	23.7	27.3	23.9±1.07		19.4	23.5	26.0	23.0±1.06
4 at cen.		20.6	23.7	26.4	23.6±0.92		19.0	21.8	25.9	22.2±1.10
4 at ends		22.9	26.1	28.7	25.9±0.92		23.6	21.3	23.1	22.7±0.39

TABLE 11.—*Comparison of yields of Marquis wheat grown on Series IV and V and rye on Series VII at University Farm under six different treatments as determined from triplicate tenth-acre plots and from 10, 9, 8, 5, and 4 square yards removed from triplicate tenth-acre plots.*

SERIES IV.

Source	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acres	Check	29.7	30.5	37.1	32.4±1.29	C	34.6	39.0	34.2	35.9±0.85
10 sq. yds.		24.4	24.7	31.4	26.8±1.26		29.8	33.8	31.8	31.8±0.64
9 sq. yds.		23.6	24.6	31.1	26.4±1.30		29.5	33.3	31.6	31.5±0.61
8 sq. yds.		23.8	23.7	31.1	26.2±1.35		30.5	33.6	31.8	32.0±0.50
5 sq. yds.		22.1	23.5	32.1	25.9±1.72		30.2	32.0	32.3	31.5±0.35
4 at cen.		22.2	24.2	32.1	26.2±1.67		30.0	31.4	33.8	31.7±0.61
4 at ends		25.3	23.3	30.2	26.3±1.13		31.0	35.9	29.9	32.3±1.02
Tenth acres	A	30.2	32.8	39.0	34.0±1.49	D	34.3	37.9	34.5	35.6±0.64
10 sq. yds.		25.1	25.3	33.6	28.0±1.56		29.5	34.8	30.8	31.7±0.88
9 sq. yds.		25.2	25.6	33.8	28.2±1.33		28.8	34.4	31.3	31.5±0.89
8 sq. yds.		23.1	24.9	33.5	27.2±1.77		28.5	34.9	30.4	31.3±1.04
5 sq. yds.		23.8	25.5	34.2	27.8±1.77		29.4	33.8	30.3	31.2±0.73
4 at cen.		23.8	25.6	34.0	27.8±1.73		29.2	32.9	31.3	31.1±0.59
4 at ends		22.3	24.2	33.0	26.5±1.82		27.7	37.1	29.5	31.4±1.59
Tenth acres	B	32.9	39.1	36.6	36.2±0.99	E	31.5	34.9	33.4	33.3±0.54
10 sq. yds.		29.8	35.0	30.3	31.7±0.91		25.2	29.5	29.6	28.1±0.80
9 sq. yds.		29.8	34.5	29.9	31.4±0.85		25.3	30.1	29.9	28.4±0.87
8 sq. yds.		29.0	35.7	31.3	32.0±1.08		24.0	29.6	30.6	28.1±1.13
5 sq. yds.		28.9	35.7	31.9	32.2±1.08		22.9	31.0	30.8	28.2±1.47
4 at cen.		28.2	36.4	32.2	32.3±1.31		23.3	30.2	29.9	27.8±1.24
4 at ends		29.9	35.1	30.3	31.8±0.93		24.7	29.2	31.4	28.4±1.09

TABLE 11.—*Comparison of yields of Marquis wheat*—Continued.

SERIES V.

Source.	Treatment.	Yields in bushels per acre of triplicate plots			Mean yield.	Treatment	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acres	Check	37.1	34.5	38.6	36.7±0.66	C	37.8	35.5	42.3	38.5±1.10
10 sq. yds.		34.8	31.4	33.1	33.1±0.54		38.8	40.6	37.9	39.1±0.44
9 sq. yds.		34.2	31.2	32.3	32.6±0.48		38.9	40.5	38.8	39.4±0.31
8 sq. yds.		35.7	32.7	33.0	33.8±0.53		39.5	41.4	37.2	39.4±0.67
5 sq. yds.		35.8	32.7	32.1	33.5±0.63		39.6	42.0	37.8	39.8±0.67
4 at cen.		36.1	32.4	32.5	33.7±0.67		39.6	42.9	37.4	40.0±0.88
4 at ends		35.4	30.6	33.6	33.2±0.77		39.3	40.2	37.0	38.8±0.53
Tenth acres	A	35.5	37.1	38.3	37.0±0.45	D	38.4	38.6	42.9	40.0±0.81
10 sq. yds.		32.6	34.4	31.8	32.9±0.42		37.0	40.5	37.3	38.3±0.62
9 sq. yds.		32.6	34.3	31.4	32.8±0.46		36.9	40.6	36.7	38.1±0.70
8 sq. yds.		32.5	35.2	31.8	33.2±0.57		37.5	40.8	37.0	38.4±0.66
5 sq. yds.		30.8	36.7	32.4	33.3±0.97		37.6	40.7	37.0	38.4±0.65
4 at cen.		32.1	36.0	31.8	33.3±0.74		36.8	41.4	37.0	38.4±0.83
4 at ends		32.9	34.4	31.9	33.1±0.40		38.2	40.1	37.1	38.5±0.48
Tenth acres	B	37.9	40.2	41.5	39.9±0.58	E	32.8	39.7	42.7	38.4±1.61
10 sq. yds.		32.8	41.1	36.2	36.7±1.33		28.0	39.1	37.4	34.8±1.90
9 sq. yds.		32.0	41.5	35.8	36.4±1.52		28.1	38.7	36.7	34.5±1.34
8 sq. yds.		32.9	41.2	36.4	36.8±1.32		27.4	38.5	37.4	34.4±1.33
5 sq. yds.		32.4	42.3	36.4	37.0±1.59		27.4	37.7	36.4	33.8±1.78
4 at cen.		30.8	42.0	35.4	36.1±1.79		25.9	37.2	35.7	32.9±1.34
4 at ends		34.9	40.4	37.4	37.6±0.88		29.0	39.9	39.1	36.0±1.93

SERIES VII.

Source.	Treatment.	Yields in bushels per acre of triplicate plots			Mean yield.	Treatment	Yields in bushels per acre of triplicate plots.			Mean yield.
Tenth acres	Check	24.6	20.9	20.7	22.1±0.70	C	29.8	29.6	29.8	29.7±0.04
10 sq. yds.		21.4	15.1	25.3	20.6±1.64		22.8	28.1	28.6	26.5±1.02
9 sq. yds.		21.9	13.6	25.6	20.4±1.96		22.4	28.4	27.8	26.2±1.05
8 sq. yds.		22.0	14.9	22.2	19.7±1.32		23.1	28.5	29.2	26.9±1.06
5 sq. yds.		21.5	13.8	25.2	20.2±1.85		22.6	28.8	26.9	26.1±1.01
4 at cen.		21.5	12.9	25.8	20.1±2.09		22.2	29.0	27.7	26.3±1.15
4 at ends		22.6	16.9	23.5	21.0±1.14		24.0	27.9	30.8	27.6±1.09
Tenth acres	A	26.7	25.1	23.6	25.1±0.50	D	31.4	25.7	32.2	29.8±1.13
10 sq. yds.		20.1	23.0	25.8	23.0±0.91		27.7	27.6	31.5	28.9±0.71
9 sq. yds.		19.4	22.8	26.4	22.9±1.11		27.7	27.8	31.2	28.9±0.64
8 sq. yds.		19.3	22.3	25.5	22.4±0.96		28.3	28.1	31.5	29.3±0.61
5 sq. yds.		20.1	22.4	27.4	23.3±1.19		26.2	27.6	31.7	28.5±0.91
4 at cen.		21.0	23.2	27.8	24.0±1.10		26.8	27.7	32.2	28.9±0.92
4 at ends		20.2	21.4	23.3	21.6±0.50		29.9	28.4	30.9	29.7±0.40
Tenth acres	B	31.0	30.3	30.8	30.7±0.12	E	28.5	26.7	30.0	28.4±0.53
10 sq. yds.		27.1	26.4	27.4	27.0±0.16		24.6	25.8	32.0	27.5±1.26
9 sq. yds.		27.1	26.4	27.8	27.1±0.23		24.8	25.9	31.8	27.5±1.20
8 sq. yds.		26.9	26.4	26.3	26.5±0.12		23.8	26.3	31.5	27.2±1.25
5 sq. yds.		28.6	25.5	27.9	27.3±0.52		23.5	26.3	31.4	27.1±1.27
4 at cen.		29.1	25.9	27.1	27.4±0.51		24.0	26.3	31.5	27.3±1.22
4 at ends		24.7	26.9	25.5	25.7±0.35		23.6	26.3	31.5	27.1±1.28

TABLE 12.—*Comparison of yields of Manshury barley grown at Waseca and Improved Ligowa oats grown at Duluth and Grand Rapids under six different treatments at determined from triplicate tenth-acre plots and from 10, 9, 8, 5, and 4 square yards removed from triplicate tenth-acre plots.*

Source.	Treatment.	Yields in bushels per acre of triplicate plots.			Mean yield.	Treatment.	Yield in bushels per acre of triplicate plots.			Mean yield.
					BARLEY AT WASECA.					
Tenth acres	Check	32.3	34.8	33.0	33.4±0.41	C	38.5	38.9	31.5	36.3±1.32
10 sq. yds.		30.5	32.3	32.6	31.8±0.35		35.7	36.3	31.1	34.4±0.91
9 sq. yds.		31.2	32.3	32.7	32.3±0.23		36.0	36.4	31.3	34.6±0.90
8 sq. yds.		30.4	32.5	32.0	31.6±0.35		34.7	37.9	29.7	34.1±1.53
5 sq. yds.		31.5	32.8	31.2	31.8±0.27		34.1	39.5	28.9	34.2±1.59
4 at cen.		30.3	34.7	31.6	32.2±0.72		33.7	37.4	28.5	33.2±1.42
4 at ends		30.5	30.3	32.4	31.1±0.35		35.8	38.6	31.0	35.1±1.22
Tenth acres	A	——	33.5	40.9	37.2±1.44	D	39.0	41.2	31.5	37.2±1.66
10 sq. yds.		31.5	32.3	37.7	33.8±1.07		34.1	39.0	32.1	35.1±1.13
9 sq. yds.		32.3	32.4	37.8	34.2±1.00		35.0	39.1	33.0	35.7±0.99
8 sq. yds.		31.9	32.0	37.8	33.9±1.08		33.3	38.9	32.7	35.0±1.09
5 sq. yds.		31.0	31.9	38.9	33.9±0.43		33.6	39.0	32.0	34.9±1.16
4 at cen.		34.6	34.8	39.2	36.2±0.83		35.5	40.4	33.3	36.4±1.16
4 at ends		29.1	29.2	36.4	31.6±1.33		31.2	37.3	32.0	33.5±1.06
Tenth acres	B	38.0	36.5	41.7	38.7±0.85	E	31.7	32.1	27.3	30.4±0.85
10 sq. yds.		36.7	34.7	35.7	35.7±0.31		27.6	31.5	29.9	29.7±0.62
9 sq. yds.		36.5	34.9	36.2	35.9±0.27		27.7	32.5	29.9	30.0±0.76
8 sq. yds.		37.7	34.7	34.8	35.7±0.54		27.2	31.6	29.9	29.6±0.71
5 sq. yds.		36.0	35.9	34.6	35.5±0.23		27.1	32.9	29.7	29.9±0.92
4 at cen.		37.6	36.7	33.5	35.9±0.69		28.0	32.9	29.5	30.1±0.80
4 at ends		37.9	32.7	36.2	35.6±0.85		26.4	30.3	30.5	29.1±0.74
					OATS AT DULUTH.					
Tenth acres	Check	36.9	54.3	55.4	54.9±0.23	C	60.1	45.5	54.4	53.3±2.34
10 sq. yds.		44.2	49.5	58.8	50.8±2.35		57.0	64.9	55.9	59.3±1.56
9 sq. yds.		46.3	50.0	59.6	52.0±2.19		56.6	66.7	56.3	59.9±1.88
8 sq. yds.		43.9	47.4	61.6	51.0±2.98		57.2	65.1	56.5	59.6±1.52
5 sq. yds.		39.7	47.2	61.3	49.4±3.49		55.9	68.8	60.4	61.7±2.09
4 at cen.		42.0	47.8	62.3	50.7±3.33		51.5	73.0	58.9	61.1±3.47
4 at ends		45.7	47.0	61.0	51.2±2.70		63.0	57.3	54.2	58.2±1.42
Tenth acres	A	55.1	56.6	50.6	54.1±0.99	D	58.0	56.4	67.4	60.6±1.89
10 sq. yds.		59.8	52.7	60.3	57.6±1.35		56.8	58.1	71.1	62.0±2.51
9 sq. yds.		58.3	51.8	61.0	57.0±1.50		55.2	58.6	66.9	60.2±1.91
8 sq. yds.		60.6	52.1	61.1	57.9±1.61		55.0	58.4	74.5	62.6±3.31
5 sq. yds.		54.4	53.8	62.4	56.9±1.53		54.7	58.9	69.5	61.1±2.43
4 at cen.		58.8	55.6	57.5	57.3±0.51		53.5	59.9	67.2	60.2±2.18
4 at ends		62.5	48.6	64.8	58.6±2.79		56.6	57.0	81.7	65.1±4.57
Tenth acres	B	57.8	57.3	56.5	57.2±0.20	E	53.4	53.3	64.1	56.9±1.97
10 sq. yds.		58.8	58.6	57.0	58.1±0.31		57.5	52.6	68.6	59.6±2.61
9 sq. yds.		58.1	60.4	56.0	58.2±0.70		57.5	53.5	66.5	59.2±2.12
8 sq. yds.		62.7	60.9	54.8	59.5±1.32		54.6	53.6	61.1	56.4±1.30
5 sq. yds.		58.9	68.4	54.5	60.6±2.26		57.3	52.7	67.6	59.2±2.43
4 at cen.		62.0	72.3	54.4	62.9±2.86		58.1	56.7	70.6	61.8±2.43
4 at ends		63.4	49.6	55.2	56.1±2.21		51.0	50.6	69.4	57.0±3.42

TABLE 12.—*Comparison of yields of barley and oats*—Continued.

OATS AT GRAND RAPIDS.

Source.	Treatment.	Yields in bushels per acre of triplicate plots			Mean yield.	Treatment	Yields in bushels per acre of triplicate plots.			Mean yield
Tenth acres	Check	27.7	31.3	28.5	29.2±0.60	C	42.2	32.0	37.7	37.6±1.48
10 sq. yds.		45.5	45.8	33.8	41.7±2.18		63.4	48.3	60.2	57.3±2.53
9 sq. yds.		47.4	43.8	33.7	41.6±2.26		66.7	45.6	60.3	57.5±3.44
8 sq. yds.		46.0	45.5	31.5	41.0±2.62		64.7	45.7	56.9	55.8±3.04
5 sq. yds.		45.9	49.2	33.4	42.8±2.65		67.2	48.8	49.4	55.1±3.33
4 at cen.		42.9	39.8	22.0	34.9±3.59		65.7	50.4	50.0	55.4±2.85
4 at ends		49.1	51.1	40.9	47.0±1.72		63.6	41.0	63.9	56.2±4.18
Tenth acres	A	28.8	27.8	28.4	28.3±0.16	D	49.5	35.0	38.9	41.1±2.39
10 sq. yds.		48.0	43.4	42.1	44.5±0.99		51.8	44.9	50.6	49.1±1.17
9 sq. yds.		46.2	42.0	38.8	42.3±1.18		53.5	42.3	50.5	48.8±1.84
8 sq. yds.		49.1	44.8	42.8	45.6±1.02		47.2	45.8	47.7	46.9±0.31
5 sq. yds.		47.3	47.3	41.9	45.5±0.99		56.3	51.5	39.9	49.2±2.68
4 at cen.		44.3	48.9	25.7	39.6±3.89		50.5	48.0	41.2	46.6±1.53
4 at ends		53.8	40.8	59.9	51.5±3.10		44.0	43.7	54.2	47.3±1.30
Tenth acres	B	44.0	31.8	33.6	36.5±1.36	E	30.8	22.5	33.8	29.0±1.86
10 sq. yds.		55.3	40.0	43.8	46.4±2.53		40.8	28.4	47.0	38.7±1.93
9 sq. yds.		54.8	37.9	43.1	45.3±2.75		40.9	27.0	46.2	38.0±3.15
8 sq. yds.		54.9	37.5	43.4	45.3±2.81		41.0	27.8	50.7	39.8±3.66
5 sq. yds.		51.2	38.4	36.5	42.0±2.54		43.5	24.7	47.8	38.7±3.89
4 at cen.		55.4	34.8	26.3	38.8±4.76		39.3	24.9	47.1	37.1±3.58
4 at ends		54.5	40.1	60.6	51.7±3.35		42.7	30.8	54.3	42.6±3.74

from the square yards which were not subject to border effect (2). Where the yields from the plots are more than approximately 5 to 10 percent higher than the yields from the yards, the difference may be due in part to the lower moisture content of the grain from the yards at the time it was weighed or to the actual size of the plots being somewhat greater than their computed area. On the other hand, where the yields of the plots are considerably lower than those from the square yards, it may be assumed that the grain from the plots was lower in moisture content than that from the square yards at the time each was weighed; that more than ordinary losses were sustained in harvesting and thrashing the product from the entire plots; or that the actual size of the plot was less than the computed size. The effect in any particular instance may be due to a combination of these causes.

At Morris the plots are separated by cultivated alleys and the series by cultivated roadways. Throughout the latter part of the growing season and at harvest the plots on Series II showed a marked border effect and those on the other two series only moderate increased growth in the border areas. Comparison of the yields from the tenth-acre plots on Series II with those from the square-yard areas removed

from them indicates slightly greater than ordinary border effect for the check and treatment A, ordinary border effect for treatments D and E, and none for treatments B and C. Since the grain in all the plots appeared to be equally affected by the alleys, some difference in size or method of handling the entire plot probably accounts for the lack of agreement between plots and yard yields in some instances. On Series III and IV where normal increases in yield due to border effect might be expected, the yields from the tenth-acre plots are from approximately 12 to 25 percent higher than the yields from the square-yard areas removed from them. Differences in the moisture content of the grain from the plots and square yards may account for this to some extent.

At University Farm on Series IV the yields indicate greater increases in some cases than can be attributed to border effect. On Series V the middle plot of each three for treatments B, C, and D was very badly lodged at harvest. The unavoidable losses during harvest account definitely for the lower yields from the entire plots than from the square yards removed from them.

On Series VII out of a total of 18 plots, 7 yielded lower from the entire areas than from the square yards removed from them. The loss in harvesting and thrashing the rye crop was practically negligible. On this series 7 plots yielding lower than the square-yard areas removed from them were probably slightly smaller than the computed size.

For the barley at Waseca no yield was recorded from the first plot of treatment A by the entire plot method. The first plot for treatment B and the third plot for treatment E are considerably lower in yield as determined from harvesting the entire plots than is indicated from the square yards. The determinations of yields by each combination of square yards agree very closely and are probably more nearly correct than those from the plots. For the other plots the relation between plot and yard yields is approximately normal.

At Duluth the first plot of the checks was injured by livestock after the square yards had been removed and, therefore, the yield is not used. For 8 of the 18 plots the yields from harvesting the entire areas is lower than from the square yards. Such differences in yield by the two methods as are indicated for the middle plot of treatments B, C, and D can be accounted for by assuming that some irregularity occurred on these plots.

At Grand Rapids the entire series was sown solid and the oats occupying the alleys between plots was discarded at harvest. The roads

surrounding the series are seeded to grass, which observations indicate depresses somewhat rather than increases yield in the end border areas. Here, then, the yields of the plots and from the square-yard areas removed from them may be expected to closely approximate each other. Inspection of the yields shows those from the entire plots very much lower in every instance, the difference amounting to over 20 bushels for individual plots, than from the square yards removed from them. These wide differences on practically all of the plots can be accounted for only by the actual size of the plots being considerably smaller than the computed size.

These differences emphasize the necessity of exercising the greatest care in all operations in determining yield on plots in order that dependable results may be obtained. Particular attention appears to be necessary in the seeding operation so that the plots may be sown uniformly to the exact desired width and more than full length so that they may be trimmed to the exact length. Sowing the plots long and trimming them to exact length at heading time obviates border effect on the ends which may raise or lower plot yields. Stretching a wire across each end of the plots in a series marking the exact length of the plots at the time the crop is 1 to 2 inches high and anchoring it firmly at frequent intervals permits the removal of the end borders very accurately and easily after the grain has headed out. Sowing the alleys between plots and removing the crop from them before harvest in such a way that the plots are left the exact width thruout is very good practice. From plots separated by alleys, the removal of an area 12 inches in width from either side of each plot largely obviates border effect (2). The removal of the border areas at any time between full heading and harvest is known to be a safe practice. How much earlier they can be removed and still secure the desired results is not known.

Cost of Determinations of Yield by the Removal of Square-Yard Areas.

The cost of determination of yield by the removal of 9 or 10 square-yard areas from plots is approximately the same as harvesting the entire areas with the binder and thrashing the grain with the ordinary thrashing machine (1).

Summary.

1. Probable errors in percentages of the mean for single determinations derived from the yields of 106 pairs of tenth-acre plots in 1918 and 168 in 1917 and from the yields of 1,073 pairs of square-yard areas in 1918 and 432 in 1917 were 4.82, 5.35, 11.52, and 9.98, re-

spectively. These probable errors are very similar to those given by other investigators for the same or similar sizes of plots.

2. The calculated probable errors in percentages of the mean squared for the yield from single determinations on the tenth-acre plots (2×8 rods) varied from 4.35 to 11.14 according to location. When the yields from the 160 tenth-acre plots are considered the calculated probable error in percentage of the mean squared for the yield from single determinations is 6.35. For this size of plot in 1917 the variation in percentage was from 4.79 to 14.74, and, when all plots were considered, it was 7.12 percent.

3. For the systematically distributed square-yard areas removed from each of 3 tenth-acre plots of similar treatment, the calculated probable error in percentage of the mean squared for yield from single determinations varied from 10.52 to 33.00 according to location. Considering the yields from 1619 square-yard areas, the calculated probable error in percentage of the mean squared for the yield from a single determination is 13.75.

For rod rows, 16.5 feet by 6 inches, which are slightly smaller than a square yard, in 1917 the variations in percentage were 9.95 to 16.83; and when all the rod rows were considered, the percentage was 12.93.

4. Comparison of the probable errors for single determinations of yield from tenth-acre plots and square-yard areas indicates that 4 to 5 systematically distributed square-yard areas removed from tenth-acre plots of relatively uniform standing grain give approximately the same probable error for yields as harvesting the products of the entire plots.

When the stands of grain were relatively nonuniform, 5 to 10 systematically distributed square-yard areas were necessary to reduce the probable errors to approximate those for the yields from the tenth-acre plots from which the square-yard areas were taken.

5. Considering the significant percentage increases in yield for the various treatments as indicated by the yields from the tenth-acre plots and from the square yards removed from them indicates that, where the crop is relatively uniform, the yields ascertained from 4 to 5 systematically distributed square yards may be safely substituted for the yields of the plot from which they are taken.

Also, when stands of the crop are relatively nonuniform, 5 to 8 square yards systematically distributed may be depended upon to give as accurate determinations of yields as the tenth-acre plot from which they were taken.

Where the crop in plots or fields is very nonuniform due to winter-

killing or to marked differences in soil or water supply, the yields from 10 systematically distributed square yard areas may not give a sufficiently accurate determination of yield to be able to substitute it with confidence for the yields of the plot or field from which they were taken.

6. Differences between the yields of individual plots other than what may properly be attributed to border effect emphasizes the necessity of greater accuracy in all operations in connection with plot test work.

7. Yields from as low as 4 and up to 10 square-yard areas systematically distributed over 3 tenth-acre plots of similar treatment indicate that reliable determinations can be made from areas as small as $\frac{1}{4840}$ acre in size, the number of areas used depending upon the degree of accuracy required.

8. The cost of removing 10 square-yard areas from a tenth-acre plot, thrashing, and weighing the product, is approximately the same as for harvesting the entire area with the binder, thrashing the grain with the ordinary thrashing machine, and weighing the product.

CONCLUSIONS.

1. The variation in the calculated probable error for the yield determinations at the different locations emphasizes the desirability of deriving probable error for use in the interpretation of the results of each test. The pairing method may be used to advantage in deriving probable error where the yields from a sufficient number of check plots is not available for this purpose.

2. Yields determined from 4 to 5 systematically distributed square-yard areas removed from plots one-tenth acre in size or less of relatively uniform crop may be confidently substituted for those from the entire plots. Under similar circumstances the yields from a greater number of square-yard areas may be considered more accurate than those from the entire plots. From very nonuniform crops the yield from 10 square-yard areas systematically distributed may not be as accurate as the yields from the entire plots.

3. The method of determining yields by the removal of relatively small systematically distributed areas, square yards or rod rows, from plots may be used to advantage:

(*a*) Where facilities for making yield determinations from entire plots are lacking;

(*b*) to check the accuracy of yield determinations on plots;

(*c*) where more accurate determinations of yield are desired than

can be secured from the limited number of larger plots than can ordinarily be devoted to a series of tests.

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A REASON FOR THE CONTRADICTORY RESULTS IN CORN EXPERIMENTS.[1]

Lyman Carrier.

Introduction.

The improvement of corn has been the aim of the wisest agriculturists of the United States for many years. Our annual production is about 1 acre of corn for every man, woman, and child in the country. It easily ranks first of all crops grown in America, both in production and total value. Any improvement in methods of growing the crop or in the inherent character of the corn itself which is reflected in a generally increased yield, adds millions of dollars to our agricultural wealth.

It would be interesting to know to what extent corn growing has been improved in the three centuries since the settlement of Jamestown and Plymouth. This is not easily determined. The early ex-

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Publication authorized by the Secretary of Agriculture. Presented at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 7, 1919.

plorers described the corn plant quite fully, and their several accounts in the main agree. They rarely gave the yields stated in terms of units of land area, and when they did so state them the distinction was not made between shelled corn and corn on the cob. They usually stated the yield in terms of the quantity of seed planted. Land was too plentiful to be worthy of consideration.

From a careful study of these early descriptions it appears safe to say that both the quality and yields of the corn grown by the Indians along the Atlantic Coast at the time of the English settlements would compare quite favorably with those of the average farmer in those sections to-day, tho probably somewhat inferior to the best improved strains grown now by the best farmers. Horse labor and machinery have been substituted for much of the hand labor performed by the Indians with clam shells and crooked sticks; otherwise the methods of culture are almost identical with those taught by Kemps and Tassore, two "fettered Indian prisoners," to the colonists at Jamestown, and by Squanto, the friend of the Pilgrims at Plymouth. The Indians had developed types of corn suitable to the varied soil and climatic conditions of America, such as the flints for the North, prolifics for the South, and dents for the corn belt, which the white farmers in three centuries have not been able to improve. The work of the American Indians with this crop is nothing short of wonderful. We have accepted and practice by necessity their methods of culture. It appears now that it would be a wise course to adopt some of their breeding methods as well.

DEVELOPMENT OF IMPROVED VARIETIES.

Efforts at improvement of corn have led to the establishing of a number of quite definite varieties. These varieties, while showing marked differences in characteristics of the ears in the country as a whole, are quite similar for the regions where they were originated. That is, there is a strong similarity in general type among the improved flint corns in the Northern States, among the improved dent corns in the North Central division of States, among the prolific corns of the South, and among the single-eared varieties of the Southwest. While this shows that no one variety is suitable for the whole country, it indicates that there is a type based on ear characteristics which is best for each region. Some of these varieties have taken the name of the community in which they first became known, as Johnson County White and Boone County White, while others carry the name of the originator, as Leaming, Reid Yellow Dent, and Cocke Prolific. The

history of any one of these varieties, so far as it is known, usually traces back to the work of some one farmer. The procedure was customarily as follows: A farmer with a definite ideal in mind began systematically to select seed corn. In the course of a few years his yields were larger than those of other farmers in his community. His corn took on a character and appearance by which it could be distinguished. His neighbors then began using this improved corn for seed. The fame of several varieties spread until they are well known throughout the nation. This does not apply to some so-called varieties which have been originated largely through the liberal use of printers' ink. In this connection it might be well to state that improved methods of culture have often accompanied the use of improved seed corn.

There is a strong similarity in the histories of the improved breeds of plants and animals. In due time corn shows were started, which brought out the score-card method of judging corn. One should never lose sight of the fact that the establishing of improved strains of corn preceded the corn shows and score cards. The latter merely emphasized the important characters in which the improved varieties of corn seemed to be superior to the common corns grown by the majority of farmers. A few farmers and experimenters began to test the score-card method of selecting seed corn. The blue ribbon corn from the shows did not always outyield the less distinguished corn at home. Then one character after another which the score card emphasized failed in carefully conducted tests to produce more than its opposing character. Tapering ears slightly outyielded cylindrical ears. There was little difference between filled tips and bare tips, smooth grains and rough grains, ears shelling a low percentage of grain and ears shelling a high percentage. Cunningham (6)[2] decided that "certain ear characters have been given more consideration than their worth as related to yield warrants, while other characters have been emphasized that may actually tend to decrease the yields." Love and Wentz (9), after reviewing the work of previous experiments and conducting extensive experiments of their own, concluded that "The judge at a corn show or a farmer in selecting his seed corn can not pick the high-yielding seed ears when judging from outward characters of the ears. It is evident that the points emphasized on a score card are of no value for seed ear purposes and are entirely for show purposes." If these conclusions are correct, the work of Reid, Riley, Leaming, and scores of other corn breeders has been greatly

[2] Figures in parentheses refer to "Literature cited," p. 113.

overestimated and the farmers who have purchased seed of these improved strains thinking they were getting something better than ordinary corn have been misled. Very few of the originators of improved varieties of seed corn ever practiced "the ear-to-row" progeny test which Love and Wentz say is "the only basis left for selecting high-yielding seed corn."

While the winning corn at the shows may not have always outyielded less perfect ears when used for seed purposes, it is an obvious fact that the highest yielding varieties of the corn belt, credited as such by public approval as well as by varietal tests, produce the largest percentage of high scoring ears. Hutcheson and Wolfe (8) have recently presented experimental data which confirm this observation. Do the results with corn in this respect differ materially from the experience of animal breeders with livestock shows and score cards?

A serious mistake which some agronomists have made has been in trying to establish one standard type of corn for the whole country, based on the improved varieties of the corn belt. The National Corn Show was a failure largely because of this error. Those who attended these shows will recall that the northern flints and the southern prolific varieties did not stand any more chance in the national competitions that a Jersey steer would at the International Livestock Show. And this in face of the fact that given rich river bottom land in the South the prolific strains will outyield the single-eared varieties of the corn belt by 50 or more bushels per acre. The corn shows and score cards when rightly used are potent influences for the improvement of corn, but they should be based on the well-established types of corn prevailing in the locality which they serve.

EXPERIMENTAL DATA UNSATISFACTORY.

A great many experiments with corn have been conducted and the published results are voluminous. It is very disappointing, however, to try to summarize these data, especially if the results are given in terms of yield of grain. The summary often presents a quantity not sufficiently positive or negative to prove anything.

CORN BREEDING METHODS.

The work of improving corn received a great impetus by the publication, some twenty years ago, of the results obtained at the Illinois Agricultural Experiment Station in increasing and decreasing the oil and protein contents of corn by systematic breeding. If such changes could be brought about in a few years there seemed to be no limit to

what might be accomplished by selection. Many corn-breeding methods came in vogue. The popularity of a method depended largely on the personality of its sponsor and the aggressiveness with which he kept his views before the public. Some very elaborate schemes were proposed for keeping records of the progeny of a selection. Just how much has been accomplished by these various methods is difficult to say. A number of varieties presumably improved by systematic selection have been put on the market; some of these have been very popular. The propaganda work with corn taken in a broad sense has been of great benefit. Farmers use better varieties, take better care of their seed corn, and practice better methods of culture because of it.

Some of the earliest experiment station work with corn attempted to decide the question whether the effects of crossing different colored corns was distinguishable in the grain formed from the cross. Some botanists felt certain there could be no such immediate effect. Experiments which proved the contrary were explained on the basis of reversion or that the seed must have been impure. Farmers from many observations knew there was an immediate effect plainly noticeable in certain cases. This debatable question was settled to the satisfaction of the scientists by the work of De Vries and Correns, which was elaborated on by Webber (10) in this country. The explanation was that corn possessed the true xenia characteristic.

Agronomists were quick to accept this scientific explanation of an obvious fact, but they have been unreasonably slow in accepting its practical application, which is, that the pollen which fertilizes the silk may influence the size and weight of the grain produced as well as its color. We still find agronomists conducting variety and ear-to-row tests where no provision is made for preventing cross-pollination.

THE INFLUENCE OF POLLEN ON SIZE AND YIELD OF GRAIN.

It is the purpose of this paper to show that the common methods of variety and ear-to-row testing of corn are unreliable in that there is overlooked this factor which may influence the results as much or more than the inherent differences in the corns under test. It seems to have been quite clearly shown that when two strains of corn are crossed there is an immediate effect on the yield of grain the same season the cross is made.

Some data which indicated such an effect were presented to the American Society of Agronomy at its annual meeting on November 14, 1910 (1). These data were not published at the time as they were

thought to be too meager to justify drawing conclusions from them. They were given in the hope that some other agronomists might confirm them or prove them erroneous. Four strains of Boone County White corn from widely separated sources had been grown side by side, but cross-pollination had been partially prevented by means of muslin screens. The 2-year average yields of these strains are 17.3, 21.6, 18.3, and 26.3 bushels of shelled corn per acre. A mixture of equal parts of seed of all four strains gave a yield of 32.4 bushels. Four strains of Leaming similarly grown yielded 27.4, 25.3, 24.4, and 26.9 bushels per acre, while the plat from the mixed seed gave a yield of 40.4 bushels. These data, with the results of some subsequent experiments which confirmed them were published in 1913 (2).

Collins (3) had previously noted that when a variety of small-grained corn from China with which he was experimenting was pollinated from a large-grained American corn, the hybrid seed "were in nearly every case distinctly larger than those showing pure Chinese characteristics." Collins and Kempton (5) afterwards found that when they mixed the pollen from two varieties of corn and applied it to the silks of one of the varieties that the hybrid seed was from 3 to 21 percent heavier than the pure seed grown on the same ear.

Webber (10) as early as 1900 gave illustrations showing differences in form of grains and his notes showed great differences in chemical composition as well as color due to xenia. He did not mention, however, that these differences might affect the yield.

Wolfe (11) made 37 crosses and found that in 27 of them there was an increase in weight of grains, ranging from 0.2 to 16.04 percent, while in 10 of the crosses there was a decrease in weight varying from 0.3 to 13.45 percent.

It can be readily seen that a factor which influences the yield to the extent which these experiments show is exerted by the pollen in the immediate grain progeny can not but render of doubtful value any variety testing of corn which is open to cross-pollination. Likewise, any experiments such as testing the correlations of ear characters and yield would be subject to this same variable influence, unless the parentage was identical for the different ears under test and also for the plants furnishing the pollen.

It has been shown in the experiments cited that the more closely a corn is inbred the greater is the effect of the foreign pollen. The speaker has often observed much larger yields of corn in his varietal tests than would likely be obtained from the varieties grown alone under field conditions. It might be noted also that the so-called pure strains or improved varieties usually yield highest in varietal tests.

Of course, there is no such thing as a pure variety of corn. Even with the careful selection for many years there has not been developed a variety which does not show a mixture of several strains. A pure strain is probably neither possible nor desirable. Inbreeding of corn has always resulted in decreased yields. This does not mean that it is not possible to establish desirable characteristics for special purposes such as soft corn for feeding, hard flinty corn for meal making, early maturing varieties, and late maturing varieties. Varieties possessing these characteristics and many more besides have been originoted. Crossing is essential and as Hayes (7) has recently shown is almost universal under normal field conditions. It would seem to be the part of wisdom for corn breeders not to strive for a pure strain, but to keep up a mixture of strains having the characteristics desired. It is better to work with nature than against her. The market standards for corn need not be disregarded or changed at all by this practice. This immediate effect of pollen influence on the yield of the grain of corn has great possibilities from its practical application.

It does not appear opportune to disregard the work of the corn improvers of the past, even if they did select their seed from the appearance of the ears rather than by ear-to-row tests. The evidence in the case seems to be that the combined judgment of thousands of farmers and seed-corn growers is that there are ear characteristics which are correlated with high yields. On the other hand, a few carefully conducted experiments indicate there is no such correlation. As previously pointed out a factor of unknown value is involved in all these tests which might increase or decrease the yield. It is not surprising that the results of so many corn experiments are of an unsatisfactory neutral character. It would seem to be best to advise farmers to continue to select seed corn after the well established types of their locality and then occasionally to introduce some seed from an outside source. The more rigidly the variety has been kept from contamination the better it is for this crossing. In making the cross the writer believes it is better to use seed of the same variety which the farmer customarily grows, but not closely related to his own strain, rather than take a chance on the results by crossing two distinct varieties. The outcross should be at least of the same general type and color as the corn which the farmer grows. It is a fairly easy matter to get unrelated strains of any of the well-known varieties of corn. There is abundant proof of a marked increase in yield of the F_1 generation from hybrid seed of two closely inbred strains of corn (4), so the farmer could expect an increased yield for at least two crops from the

cross. No technical skill would be required to mix the seed at planting time.

Corn still offers great opportunities to the agronomist who will break away from the old methods of conducting experiments and work in the light of all the known facts regarding this crop. A method must be followed which will allow the plants to develop normally and at the same time effectually control the matter of pollination. The equipment for such experiments will be expensive, but relatively no more so than that used in lysimeter and some other work. The importance of the corn crop would seem to justify any such outlay of public funds.

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THE EFFECT OF THE ENVIRONMENT ON THE LOSS OF WEIGHT AND GERMINATION OF SEED POTATOES DURING STORAGE.[1]

O. BUTLER.

Potatoes generally lose from 10 to 16 percent of their weight during storage and germinate long before they can be planted, thereby necessitating "sprouting," an operation which lowers the quality of the tubers for seed. Under what conditions can loss of weight be reduced and germination retarded to the desired degree? A study of the factors constituting the environment of stored tubers will give us the information necessary for the practical solution of the problem. These factors are temperature, oxygen supply, and humidity of the air.

TEMPERATURE.

The temperature at which potatoes are stored has a very marked effect on the rate of loss of weight, as is shown by the data presented in Table 1.

TABLE 1.—*Effect of temperature on the loss of weight of potatoes.*

Mean temperature of storage.	Loss of weight after—						
	30 days.	60 days.	90 days.	120 days.	150 days.	180 days.	210 days.
°*C.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
3.74	0.58	1.43	1.43	2.29	2.88	2.15	2.44
8.82	1.26	2.53	3.37	4.21	7.18		
15.75	1.52	2.77	4.01	6.65	11.56		

A consideration of the data in Table 1 shows that, while at the mean temperature of 8.82° C. the loss of weight of stored potatoes becomes increasingly rapid with age, at 3.74° C. the loss practically ceases after the hundred and twentieth day. This effect of low temperature is not unusual and I gather from experiments made in a cold-storage warehouse that, between 0 and 4° C. at least, loss of weight will fluctuate around a mean value. The reason for this peculiar behavior is of course apparent when one takes into consideration the fact that starch in potatoes suffers an increasingly rapid

[1] Contribution from the New Hampshire Agricultural Experiment Station, Durham, N. H. Received for publication December 28, 1918.

hydrolysis as the temperature falls below 8° C.,[2] thereby causing the loss of weight due to transpiration and respiration to become more or less perfectly balanced by the gain in weight due to sugar accumulation. It is therefore clear that from the point of view of loss of weight storage at low temperature is highly desirable. But is any advantage to be derived from storing potatoes at a mean temperature lower than 3.74° C.? It seems to me that no material advantage would accrue, since germination is sufficiently delayed for all practical purposes (210 days) when the tubers are stored at this temperature.

OXYGEN SUPPLY.

In the potato the loss of weight on keeping is in part due to respiration. Hence, a reduction in the available oxygen supply will lower respiratory activity and retard metabolic changes. It is of course evident that potatoes would decompose in the absence of all oxygen, and that asphyxiation would result were the oxygen reduced beyond a certain minimum variable with the temperature.[3] Potatoes will keep in excellent condition in silo provided the temperature does not fall too low and Schribaux[4] has pointed out that tubers stored in a cellar and covered with a layer of soil sufficiently deep will keep in a perfect state of preservation until August, while if they are covered to a lesser depth they will grow and produce a crop of young tubers of excellent quality, or if only lightly covered germinate in the usual way.

In order to test the effect of reducing the oxygen supply on loss of weight and retardation of germination an experiment was set up in the following manner, using three tubulated bell-jars of the usual pattern as recipients for the potatoes. In bell-jar No. 1 the tubulures were plugged with cotton, thus allowing a free diffusion of gases; bell-jar No. 2 was connected with a water siphon and 8 percent of the contained air was renewed daily; bell-jar No. 3 was also connected with a water siphon, but only 0.8 percent of the air was renewed every 24 hours. The temperature during the course of the experiment ranged between 8° and 10° C.

A few days after the experiment was set up the air in all three bell-jars became saturated with water vapor and eventually the potatoes

[2] Muller-Thurgau, H. Über Zuckeranhaufung in Pflanzen-Theilen in Folge nieder Temperatur. *In* Landw. Jahrb., 11: 757–818. 1882.

[3] In this connection the reader may consult Stewart, F. C., and Mix, A. J., Blackheart and the aeration of potatoes in storage, N. Y. State Agr. Expt. Sta. Bul. 436, 321–362. 1917.

[4] Schribaux, E. Apropos d'une methods de conservation des pommes de terre. *In* Jour. Agr. Prat., n.s., vol. 7. 1914.

molded. At the end of 90 days, when the experiment was discontinued, the air in all the bell-jars was very musty, but the potatoes were all sound and pure. The potatoes in bell-jar No. 1 had germinated, the sprouts being short and stout and having formed roots from 1 to 2 inches long, rather freely covered with root hairs. In bell-jar No. 2 germination was just beginning, but in bell-jar No. 3 there were no signs of growth. The loss of weight of the potatoes during the course of the experiment was as follows:

Method of treatment.	Loss of weight after 90 days
Free diffusion of air	1.55 percent
8 percent of volume of air renewed daily	0.72 percent
0.8 percent of volume of air renewed daily	0.58 percent

The data presented clearly show that loss of weight can be materially curtailed by reducing the oxygen supply and that asphyxiation does not occur at 8 to 10° C. even when as little as 0.8 percent of the volume of air is renewed daily during 90 days.

In an experiment on the effect of reducing the oxygen supply on the keeping quality of potatoes in which the environment was dry air at 9.31° C. instead of air saturated with water vapor, the results shown in Table 2 were obtained.

TABLE 2.—*Effect of reduced oxygen and dry air on the loss of weight of potatoes during storage.*

Method of treatment	Loss of weight after—				Germination.
	30 days.	90 days.	150 days.	207 days.	
	Percent.	*Percent.*	*Percent.*	*Percent.*	
In reduced oxygen.	1.79	4.77	9.21	13.52	None
In air ..	3.37	6.15	9.42	15.16	After 99 days

The potatoes in reduced oxygen were placed in a rectangular galvalized vessel capable of holding about 85 pounds of potatoes. On the bottom of the vessel calcium chloride was spread. Next a wire false bottom was set in and the vessel fillled with potatoes to about 2 inches from the cover. The remaining space was occupied by a loosely fitting tray containing calcium chloride. The air was introduced on one side of the vessel below the false bottom and withdrawn from the opposite side of the cover. One percent of the air was renewed daily by means of a water siphon.

The data in Table 2 show that germination can be prevented more effectively by reducing the oxygen supply than by lowering the temperature, as no signs of germination in reduced oxygen at a mean

temperature of 9.31° C. occurred in 207 days. while at a mean temperature of 3.74° C. germination had already begun in 210 days. The loss of weight of potatoes stored in reduced oxygen and dry air is, however, higher than desirable. The air surrounding the tubers should evidently not be too thoroly dried if loss of weight is to be reduced to a parity to that occurring when tubers are stored at 3.74° C. The experiments just detailed was therefore repeated, using calcium chloride only on the tray at the top of the container. Under these conditions the results obtained were entirely favorable, as the following figures show. The mean temperature during storage was 9.39° C.

Method of treatment	Loss of weight after 90 days	Loss of weight after 120 days.
Potatoes in air	8.96 percent.	17.24 percent.
Potatoes in reduced oxygen	1.35 percent.	2.79 percent.

The potatoes in reduced oxygen when the experiment was brought to a close on May 25 were in perfect condition and had not germinated, while those in air had long sprouts and were shriveled and flabby.

HUMIDITY.

Potatoes lose weight less rapidly, other things being equal, in moist than in dry air. In air saturated with water vapor potatoes will keep a certain length of time but finally mold and soften, while if the air in which they are stored is very dry they lose water rapidly and become flabby. The effect of dryness of the air, all other conditions being equal, on the loss of weight of potatoes is strikingly shown by a comparison of the figures just presented with those given in Table 2. Casting the absolute values into relative numbers and considering the temperature of storage as having been the same in both experiments (it was actually 9.31 and 9.39° C., respectively), we obtain the results shown in Table 3.

TABLE 3.—*Effect of dryness of the air on the loss of weight of potatoes.*

Method of treatment.	Relative loss of weight after—	
	90 days.	120 days.
Stored in air	100.00	100.00
Stored in dry air	77.56	89.74
Stored in reduced oxygen, air partially dried	15.06	16.18

It is perfectly clear that loss of weight of potatoes during storage is very markedly affected by the relative humidity of the air. In fact, relative humidity is an even more potent factor in reducing loss of

weight during storage than temperature, as we find that a reduction of temperature from 8.82° C. to 3.74° C. lowers the loss only 1.8 times, while a change from dry to moderately dry air effects a saving more than 2.7 times greater for a period of storage of the same length, i. e., 120 days.

SUMMARY.

We have found in the course of our study of the factors constituting the environment of stored tubers that:

Germination can be satisfactorily retarded by lowering the temperature to 3.74° C., or by reducing the oxygen supply to an extent which is tantamount to storing in "dead air."

Germination can be retarded by storing in "dead air" at a mean temperature of 9.31° C. more effectively than by storing in free air at 3.74° C.

Loss of weight is markedly affected by the relative humidity of the air. Saturated air and dry air are both to be avoided, the former because transpiration is inordinately increased and the latter because condensation of water vapor occurs, forming a nidus favorable to the development of molds.

RELATION OF VARYING DEGREES OF HEAT TO THE VIABILITY OF SEEDS.[1]

James L. Burgess.

The practical difficulties found in the use of carbon disulfide for the destruction of insects and insect eggs in stored seeds have suggested the idea that heat might, under certain conditions, replace it in the control of insect pests. Professor George Dean, of the Kansas Agricultural Experiment Station, made a practical test of this idea with mill insects.[2] In the summary of the results of his experiment he says, "No mill insect can withstand, for any length of time, a temperature of from 118° to 122°." He found, moreover, "the destruction of insects by means of heat to be the most practical, efficient, convenient, and least expensive method."

[1] Contribution from the North Carolina Seed Laboratory, North Carolina Department of Agriculture, Raleigh, N. C. Presented at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 6, 1919.

[2] Dean, George. Further data on heat as a means of controlling mill insects. *In* Jour. Econ. Entom., 6, no. 1, p. 40–53. 1913.

But, while Professor Dean gave us what seems to be a practical method for killing insects on a large scale, he does not seem to have ascertained the effect his caloric treatment of the insect has on the vitality of the seed it infests. While a high temperature, short of burning, may not seriously injure the edible qualities of grains, there is no question but that great care must be taken to find the critical temperature above which the viability of these grains will be lowered. With a view, therefore, of ascertaining this critical temperature for various seeds the North Carolina Seed Laboratory undertook a series of temperature tests, varying both the time and the temperature by holding the temperature at, say, 140° for 1, 3, and 5 hours, respectively; and by subjecting the seeds for very short periods to very much higher degrees of heat, say, 212° for 30 minutes, 300° for 5 minutes, etc., decreasing the time and increasing the temperature.

The experiment was run with corn, wheat, oats, rye, cowpeas, soybeans, and garden beans—seeds most liable to insect depredations. Our results were in some cases vitiated by accident, thus rendering this discussion of more academic than practical interest.

Of course it is evident that seemingly unavoidable difficulties lie in the way of destroying, by heat, those insects that bury themselves deeply in the masses of grain; but weevils and other insect enemies of stored seeds generally begin their work in the surface where they can be most easily attacked by heat. Moreover, some ingenious brain may find it possible to construct a form of hot blast against and through which seeds may be forced in such a way that both insects and insect eggs can be killed in the operation.

We were unable to do anything with that part of our plan requiring the seeds to be subjected to very high temperatures for very short periods. So far as carried out the results of the work are shown in Table 1. In all cases dry heat was used and applied in a hot air sterilizer, the temperatures being measured by a Fahrenheit thermometer.

A temperature of from 140 to 158 degrees continued through five hours had no appreciable detrimental effect on the viability of garden beans. No check test was used.

Cowpeas were more susceptible to the influence of heat and were almost killed by a temperature of 194° continued through a period of 5 hours, while a temperature of 140° for 1 hour did not seem to effect the viability to any great extent. No check test was used.

Soybeans were practically unaffected by a temperature ranging from 140° to 194°, running through a period of 1, 3, and even 5 hours. No check was used.

TABLE 1.—*Viability (percentage of germination) of field seeds after exposure to various temperatures for one to five hours.*

Temperature	Length of exposure.	Kind of seed.						
		Garden beans.	Cowpeas.	Soybeans	Corn.	Oats.	Rye.	Wheat.
° F.	*Hours.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
140	1		82	98		98		
	5	92	66	98				
158	3			96				
	5	90	32			97		69
176	1	90		98	68			
	3	92	78	100	32			
	5		24	90			100	60
194	1			100				68
	5		2			98	93	
212	5						92	
230	1							60
	3						78	55
248	1						0	0
	5						0	
Check					94	90	91	92

Our tests with field corn were not satisfactory, as we got only two tests to which we could attach any importance. These showed that 176° for 1 hour reduced the viability to 68 percent and for 3 hours to 32 percent. The check test showed a germination of 94 percent.

Our results with oats were also unsatisfactory, but three tests proving of any interest. These three tests seemed to show no appreciable difference in the effect on the seed of a temperature ranging from 140° to 194°, running through periods of 1 to 5 hours. Due to what must have been an experimental error, the check test showed lower viability than the heat tests.

In our tests of rye temperatures of 176° to 212° carried through 5 hours showed practically no detrimental effect on the viability of the seeds. A temperature of 230° for 2 hours reduced the viability to 78 percent, however, and a temperature of 248° for 5 hours killed the seed.

Wheat was seriously affected by high temperatures. The viability in this test was reduced to 60 percent by a temperature of 230° carried through 1 hour and to 55 percent by the same temperature carried through 3 hours. The germ was killed by a temperature of 248° carried through 1 hour. The check showed a viability of 92 percent.

It will be noted that the lowest temperature used, 140° F., was 10° higher than that found by Professor Dean to be sufficient to kill insects. This temperature, and very much higher temperatures, some as high as 194° F., seemed to show no detrimental effect on the viability of soybeans, oats, and rye. It is not known whether these temperatures will kill insect eggs.

COMMUNITY COTTON IMPROVEMENT IN NORTH CAROLINA.[1]

R. Y. WINTERS.

Rural communities that boast of good roads or good schools are not uncommon; but one rarely finds a community that takes pride in the quality of seed it produces. On the contrary, it is the custom of most communities to secure a large proportion of their seed from other localities. This is particularly true of the small cotton growers. Very few growers realize the value of home-bred and home-grown seed. Some even believe that crops deteriorate when grown in the same locality for several years. This delusion and misleading advertisements are partly responsible for the lack of uniformity in cotton varieties. With each grower of a community changing cotton seed every few years one can very well imagine the effect upon uniformity and quality of staple.

A survey of cotton varieties in a North Carolina community would read somewhat as follows: Two growers planting Half-and-half; four, Cook; ten, King or a variety of similar origin; and three growing Cleveland Big Boll or some other large-bolled variety. Each grower swears by his particular variety but is usually not sufficiently interested to prevent its mixing with other varieties at the public gin. Assuming that these varieties are fairly pure, the community would be producing a little ⅝- to ¾-inch cotton, quite a bit of ¾- to ⅞-inch, a small amount of 15/16- to 1-inch, and in some communities a little long-staple cotton. Such a group of cottons is sometimes found on a single farm. This condition and the mixing of seed at the public and private gins render the production of uniform strains of cotton almost hopeless.

Considering our market conditions, the responsibility for lack of uniformity cannot be placed entirely on the producer. To the average buyer cotton is cotton, to be bought as cheaply as possible. Until improved quality and uniformity mean increased price to the grower, we cannot expect a general production of better cotton. The work of cotton improvement, therefore, requires the attention of the market expert as well as that of the breeder.

[1] Contribution from the North Carolina Extension Service, North Carolina Agricultural and Mechanical College, West Raleigh, N. C. Received for publication January 20, 1919.

VALUE OF COMMUNITY ACTION.

To improve these conditions in North Carolina, the extension service has established the community cotton improvement work. By community cotton improvement is meant the selection of one good variety of cotton for a community, and its improvement in the community by saving seed from the best plants. Such a scheme should improve the yield and quality, lessen the danger of mixing at the gin, and render the community more independent of local markets.

METHODS AND RESULTS.

Those who have dealt with community work of any sort no doubt realize that the greatest problem lies in the securing of community action or cooperation. In this connection, some of the methods used and results obtained in our community cotton improvement work may be of interest.

Previous to the fall of 1914, our cooperative cotton improvement work was conducted with individual growers. The work with individuals was slow and often unsatisfactory. During the summer of 1914, the matter of community cotton improvement work was discussed before the State meeting of farm demonstrators with the hope of securing their cooperation, and that winter one community made application for the work. Since that time sixteen communities in eleven counties have taken it up.

Each year the county agents are instructed regarding the purpose and methods of community cotton improvement. The matter of interesting and organizing the community is left to them. When the growers of a community become sufficiently interested, application is made to the extension service for cooperation. Upon the approval of the application a meeting is arranged by the county agent. A representative of the experiment station meets with the growers to discuss the advantage of growing one good variety in the community, and suggests that this variety be chosen by conducting a varietal test which will include five varieties grown in the community and five recommended by the station. This is discussed and voted on by the growers present. If the cooperation is continued and the growers agree to choose and improve one variety of cotton in the community, the extension service agrees to help in making the varietal test and in improving the variety chosen. A census is taken of the varieties most generally grown in the community and five are selected for the test by the growers present. The station recommends varieties which have yielded best under similar soil and climatic conditions.

On account of the increasing demand and better price paid for the 1- to $1\frac{1}{16}$-inch cotton, special efforts are being made to introduce varieties which will furnish a uniform staple of this length. From a list of plots offered one or more are selected for making the test. Care is used to select a uniform piece of ground which represents the prevailing soil type of the community. Other conditions being equal, the test plot is located on a public road or on a part of the farm easily reached by growers of the community. The variety test is planted and harvested under the supervision of the county agent and a representative of the station.

When the test has been planted a circular letter, explaining the test and its object, is sent to the cotton growers of the community During the growing season the test is visited several times by the county agent and at least once by a member of the station staff. In the fall when the yields have been secured, the results are given in a simple report which is mailed to the growers of the community in the form of a circular or circular letter. During the winter a meeting is held to decide upon the variety to be improved. The variety is selected by a vote of the growers. After the selection is made, the growers are furnished with the best source of seed for the variety chosen. In the spring a few growers plant their entire crop in the new variety and others plant enough to get their next year's seed. Growers of the community who wish to further improve the variety are given instructions in field selecting and plant-to-row breeding. The actual field selection and plant-to-row plantings are followed until a uniform strain is established and one or more growers of the community have been taught the plant-to-row method of selecting. This usually takes three years.

During the past three years the extension service has helped to introduce a good strain of cotton into sixteen communities of eleven counties. In the varietal tests the new strains have yielded an income of $10 to $60 per acre more than the varieties previously grown in the communities. Table 1 contains the results obtained in a community of Halifax County and is a fair example of similar tests in other communities.

This community in Halifax County was called to our attention by the Division of Markets in 1915. As a result of its cotton-grading work this community was found to produce a very poor quality of cotton. Among 949 bales of cotton sampled, 209, or 22 percent, stapled less than seven-eighths of an inch in length. Compared with other communities of the State this community ranked low in grade

TABLE 1.—*Results obtained in a community cotton varietal test in Halifax County, N. C., in 1916.*

Variety.	Yield in pounds per acre.			Percentage of lint.	Length of staple, inches.	Value of lint per pound, cents.	Total value of lint and seed per acre.[a]
	Seed cotton.	Lint.	Seed.				
Cleveland	1,960	784.0	1,176.0	40.0	$\frac{16}{16}$	20	$197.96
Cleveland	1,510	566.2	943.8	37.5	$\frac{7}{8}$–1	20	146.27
Mexican	1,270	457.2	812.8	36.0	$1\frac{1}{8}$	23	133.60
Ricks	1,400	490.0	910.0	35.0	$\frac{7}{8}$	20	129.85
Medford	1,300	494.0	806.0	38.0	$\frac{7}{8}$	20	127.01
Cook	1,290	490.2	800.0	38.0	$\frac{7}{8}$	20	126.04
Trice	1,420	468.6	951.4	33.0	$\frac{7}{8}$	20	127.02
Simpkins	1,170	432.9	737.1	37.0	$\frac{7}{8}$	20	112.38
Hawkins	1,190	422.5	767.5	35.5	$\frac{15}{16}$	20	111.36
Durango	880	325.6	554.4	37.0	$1\frac{1}{8}$	27	107.31

[a] Estimates based on middling cotton at 20 cents per pound and cottonseed at $70.00 per ton, the prices quoted December 7, 1916.

and length of staple produced. When a survey was made of the varieties grown in the community it was found that most of its cotton came from poor strains of Simpkins, Ricks, Medford, and Hawkins. These are all early small-bolled varieties which usually yield a short staple of poor quality. Most growers of the community were of the opinion that the large-bolled varieties were too late for that section, though the varietal test showed that the better large-bolled varieties not only matured but produced almost as much cotton at the first picking as was produced in two pickings from the small-bolled varieties. Last season the growers of this community bought 207 bushels of the improved seed, and enough has been saved this season to supply the entire community with improved seed. This condition has also made it easier to further improve the strain for that section.

In addition to the cotton improvement work efforts are being made to improve the market conditions. The Office of Markets is cooperating in this work by grading the community cotton and locating markets for special grades of cotton. A register is kept of growers who produce well-bred seed, and a special effort is being made to create a local demand for all improved seed. When a grower fails to select his seed, or allows it to become mixed, his seed is no longer recommended.

In most communities the ginners have given cooperation. In a few cases certain ginners have refused to gin cotton other than that chosen by the community, while others have set aside special days for ginning community cotton.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the February issue was 515. Since that time 6 new members have been added, 2 have been reinstated, and 8 have resigned, so that the net membership remains at 515. The names and addresses of the new and reinstated members, the names of those who have resigned, and such changes of address as have come to the notice of the editor and secretary follow.

New Members.

Anderson, Mr., Russian Dept., R. Martens & Co., 6 Hanover St., New York.
Bussell, Frank P., 111 Delaware Ave., Ithaca, New York.
Grisdale, F. S., Vermilion, Alberta, Canada.
Jones, D. F., Agr. Expt. Sta., New Haven, Conn.
Pendarvis, Chas. E., Media, Ill
Sampson, Homer C., Dept Botany, O. S. U., Columbus, Ohio.

Members Reinstated

Hanger, W. E., Ohio State University, Columbus, Ohio.
Holbert, J. R., Bloomington, Ill.

Members Resigned.

Babcock, F. R.,
Bailey, C. H.,
Call, L. E.,
Goddard, L. H.,
Grimes, W. E.,
Nash, C. W.,
Schuer, Henry W.,
Stone, J. L.

Changes of Address.

Barbee, O. E., 901 Linden Ave., Pullman, Wash.
Chapman, James E., Raymondville, Texas.
Cron, A. B., Chillicothe, Texas.
Deatrick, Eugene P., Mont Alto. Pa.
Doneghue, R. C., County Agent, Macomb, Ill.
Foersterling, H., Abor Farm, Jamesburg, N. J.
Frear, D. W., Sacaton, Ariz.
Furry, R. L., Carrollton, Mo.
Gordon, Thos. B., 27 Board of Trade Bldg., Louisville, Ky.
Hendry, Geo. W., University Farm, Davis, Calif.
Hill, C. E., Experiment Farm, Waterville, Wash.
Jensen, L. N., Box 1214, Amarillo, Texas.
Moomaw, Leroy, Experiment Farm, Dickinson, N. Dak.
Plummer, J. K., 218 New Berne Ave., Raleigh, N. C.
Reed, E. P., Urbana, Ohio.
Richards, P. E., Maryland Expt. Sta., College Park, Md.
Taggart, J. G., Vermilion, Alberta, Canada.
Van Nuis, C. D., Agr. Expt. Sta., Durham, N. H.

REPORT OF THE SECRETARY-TREASURER.

November, 1917, to March, 1918.

Note.—The following report was made by Secretary-Treasurer P. V. Cardon to the Executive Committee of the American Society of Agronomy at the time of his resignation in March, 1918, when he was succeeded by Lyman Carrier. It should have been printed along with the report of Secretary Carrier in the December issue of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY, but unfortunately a copy was not available to the editor at that time. With the report of Secretary Carrier, it makes a complete record of the Society's finances for 1918. Summarizing the two reports, it is shown that the total receipts of the Society for the thirteen and one half months covered by them were $1,796.98, which, with the balance of $645.97 turned over by former treasurer Roberts, makes a total of $2,442.95. The total expenditures during the period were $1,877.95, leaving a balance, as shown by the report of Secretary-Treasurer Carrier, of $565.—EDITOR.

This statement is submitted as a record of the official actions of the retiring Secretary-Treasurer of the American Society of Agronomy from the date of his election at the November, 1917, meeting of the Society to March, 1918, the time of his resignation.

During his brief incumbency, the retiring Secretary-Treasurer enjoyed the courteous cooperation of all officials and members of the Society and he regrets that he was unable personally to meet and extend his acquaintance among all the active agronomists who are supporting this organization. He wishes especially to thank Messrs. C. W. Warburton and George Roberts for their assistance in combining the affairs of the old offices of Secretary and Treasurer, and to express his appreciation of services rendered by Messrs. Albert F. Stouffer and J. M. Alfaro.

1. AMENDMENT TO CONSTITUTION.

At the tenth annual meeting of the Society, held in Washington, D. C., November 12 and 13, 1917, the retiring Secretary and Treasurer recommended that the two offices be merged and this was done by the election of one man to both. As previous notice had not been given, it was not possible to amend the constitution at the meeting to make that merger legal, but the Executive Committee at its meeting on November 14 voted to submit the necessary amendment to the Society.

Accordingly, each member of the Society was asked to mail to the Secretary-Treasurer his vote on the following question:

Shall Article 4 of the Constitution of the American Society of Agronomy be amended to read "The officers of the American Society of Agronomy shall be a President, a First Vice-President, a Second Vice-President, and a Secretary-Treasurer."

All of the votes received to date, a total of 163, are in the affirmative.

2. RECEIPTS.

The following is a classified list of funds received by the Secretary-Treasurer. The last report of former Treasurer Roberts showed a balance of $656.22, tho

only $645.97 was received from him by the writer. This apparent discrepancy is due to the fact that after making his report Mr. Roberts received $10.00 covering five membership dues for 1917 at $2.00 each and paid out $20.25, as shown by his vouchers number 132 and 133, leaving a balance of $645.97.

Funds Received by Secretary-Treasurer—November 20, 1917, to March 1, 1918.

Geo. Roberts, balance from former treasurer		$645.97	
C. W. Warburton, collections by secretary		44.06	
Membership fees received		813.70	
9 members for 1917 at $2.00	$ 18.00		
1 member for 1918 at 1.50	1.50		
4 members for 1918 at 2.00	8.00		
309 members for 1918 at 2.50	772.50		
3 student members for 1918 at $2.00	6.00		
6 local members for 1918 at .50	3.00		
1 member for 1919 at $2.50	2.50		
Exchange on checks	.20		
Library subscriptions		151.26	
Through agencies	$ 49.76		
Direct	101.50		
Sale of *Proceedings* and JOURNAL		47.45	
Reprints		20.04	
Total receipts			$1,722.48
Less payments by postage stamps			2.45
Cash receipts			$1,720.03

3. DISBURSEMENTS.

The following expenditures have been made by the Secretary-Treasurer:

New Era Printing Co., printing JOURNAL		$ 444.23
Dec. 3, 1916	$355.61	
Jan. 25, 1917	88.62	
E. B. Thompson, Dec. 3, 1917, stereoptican and operator		22.50
Lewis M. Thayer, printing		49.50
Dec. 8, 1917	$32.50	
Jan. 9, 1918	13.25	
Feb. 7, 1918	3.75	
Maurice Joyce Eng. Co., engravings		44.54
Jan. 2, 1918	$ 4.50	
Jan. 22, 1918	6.99	
Feb. 7, 1918	6.50	
Feb. 20, 1918	26.55	
Washington Electrotype Co., maps		5.00
M. O. Chance, P. M., postage stamps		25.00
Dec. 12, 1917	$20.00	
Jan. 24, 1918	5.00	
C. W. Warburton, editor's expenses		18.10
C. R. Ball, acting editor's expenses		4.25
Albert F. Stouffer, typewriting		15.50

J. M. Alfaro, typewriting		8.50
Feb. 9, 1918	$2.50	
Feb. 28, 1918	3.50	
March 1, 1918	2.50	
Total disbursements		637.12
Cash balance on hand		1,082.91
		$1,720.03

4. MEMBERSHIP.

The last report of the Secretary gave the membership of the Society as 652. Since that time 32 members have been added, 1 has been reinstated, 1 has died, 15 have resigned, and 31 have been dropped for nonpayment of 1917 dues, leaving a net membership of 638.

The Secretary-Treasurer has been notified of 35 changes of address and of 20 instances where members have joined the Army or Navy.

Respectfully submitted,

P. V. CARDON.

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CARRYING CAPACITY OF NATIVE RANGE GRASSES IN NORTH DAKOTA.[1]

J. H. SHEPPERD.

For many years the writer has believed that a large area of land in the western half of North Dakota should be kept in native prairie sod for pasturing live stock and has held that it will produce vastly more return in that way than can be obtained from the same land if plowed and cropped.

The 1908 report of the field operations of the Bureau of Soils of the United States Department of Agriculture, covering a survey of the portion of North Dakota lying west of the hundredth meridian, confirms this view and in its statement lists 6,645 square miles of land which I interpret from their description is adapted only for grazing. The land west of the hundredth meridian in North Dakota constitutes about three-fifths of the area of the State. The rough or grazing land constitutes about 17 percent of the area, and is equivalent to 184 townships of land.

In 1913 an active campaign on the part of the writer resulted in an arrangement for a trial to determine the carrying capacity of a native range pasture of wild grasses to be conducted cooperatively by the North Dakota Agricultural Experiment Station and the United States Department of Agriculture on the Northern Great Plains Field Station at Mandan, N. Dak. John T. Sarvis and the writer, representing

[1] Contribution from the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak., being a report of work conducted cooperatively by that station and the United States Department of Agriculture. Presented at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 6, 1919.

the two cooperating agencies, have been responsible for the plans and have carried out the details of the experiment.

The land used for this trial is Section 16, Range 81, Township 138. It is within the Williston loam series of soils and located in what is locally called Custer's Flats, 3.5 miles due south of the city of Mandan, N. Dak. The land is on meridian 101 just south of the 47th degree of north latitude. The elevation is 1,929 feet. The following weather data have been recorded:

The average precipitation for 40 years, 1875 to 1914, is 17.41 inches.
Greatest annual precipitation was in 1876, 30.92 inches.
Lowest annual precipitation was in 1889, 11.03 inches.
Greatest precipitation in one month was in June, 1914, 10.68 inches.
Mean seasonal precipitation, April 1 to July 31, inclusive, 9.91 inches.
Month of maximum precipitation, June, 3.5 inches.
Month of minimum precipitation, February, 0.5 inch.
The coldest temperature recorded was in January, 1916, —45° F.
The hottest temperature recorded was in July, 1910, 107° F.
Average date of last killing frost in spring, May 15.
Average date of earliest killing frost in fall, September 15.
Record latest spring frost, June 7.
Record earliest fall frost, August 23.
Prevailing wind, north; usual velocity, 5 to 10 miles per hour.

This section of land, with the exception of 50 to 60 acres, is nearly level and while it differs from most grazing land in that particular permits the laying out of more uniform and comparable pastures than could otherwise be had. The soil type is fairly typical of a large area in western North Dakota. The rough land is set off for a reserve pasture and hence does not enter into the trial.

The section of land used for the trial had been a hay meadow for several years previous to 1915. Some portions of it had been mowed in 1914. Where these cut areas occurred the cattle grazed more readily than they did where it had not been mowed, as that operation had removed much dead grass. As prairie grass covers go, this pasture was densely covered with vegetation at the start.

The object of the trial is to determine the carrying capacity of native pastures without regard to their maintenance or improvement. When this factor is worked out consideration can be given to different methods and periods of grazing.

In 1915, the entire 250 acres set aside for the experiment was fenced as one field and pastured on the basis of 5 acres to the steer. This was done to study its carrying capacity and to get the land in uniform condition. In 1916 the grazing land was divided into four pastures, as shown in figure 10. These pastures contain 30, 50, 70, and 100 acres respectively.

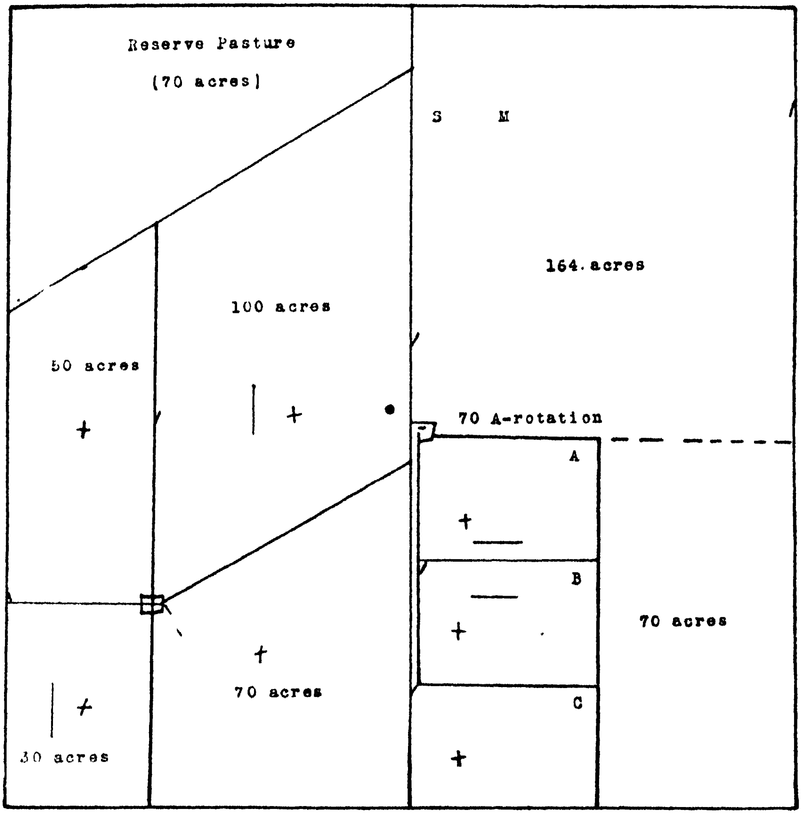

FIG. 10. Plot of the section used in the grazing experiments at Mandan, N. Dak. The corrals and sheds are at the center of the pasture. The straight lines within the various areas represent isolation transects. The crosses show the location of the mapped quadrats. Soil samples are taken around these areas. The dot in the center of the section shows the location of the well. The letters S and M in the northeast quarter of the section represent seeding and mowing experiments respectively.

Corrals, board shelter sheds open on the south, scales, and a squeeze for branding were arranged at the converging corners of the four pastures, and water was provided there for all of the cattle. A 70-acre rotation pasture was begun in 1918 and water was provided separately in the corner of that field.

Ten 2-year-old grade beef-bred range steers are the standard grazing force for each pasture, which makes the pasturing ratio 3, 5, 7, and 10 acres of grass area to the 2-year-old steer.

By correspondence and questionnaires the estimates of about two hundred farmers on the carrying capacities of native and domestic pastures for that region of the State were secured. They range from 6 to 12 acres of native grasses for a 2-year-old steer.

One of the first factors to be determined in this trial seemed to be that of the unit of measure in pasturing with cattle. The 2-year-old beef steer was decided upon as the unit, as (a) he seemed to be the unit most used by ranchmen figuring on this question; (b) he has about the average capacity for consumption between yearlings, cows, and large steers; and (c) he is not disturbed like the heifer by periods of oestrum or by calving during the trial.

The trial calls for 55 head of 2-year-old steers each year. It has been difficult to find suitable animals on the market in the spring, and yearling cattle have had to be used in part for two seasons. Consequently, the comparisons of the consuming and gaining capacity of yearling steers and 2-year-olds are features which have been strongly forced upon us for consideration. This matter has been disposed of by placing approximately a standard weight of cattle per pasture on the land and by comparing the total gains in live weight per pasture and per acre. The weights of the animals when put on the different pastures each year are shown in Table 1.

TABLE 1.—*Weight and number of cattle per pasture by years.*

Year.	Pasture	Number of head.	Weight of cattle per pasture.	Days pastured.	Average weight per head.
			Pounds.		*Pounds*
1915	All as one (250 acres)	53	42,745	109	806.5
1916	100-acre	14	8,705	149	621.8
	70-acre	12	7,580	149	631.8
	50-acre	12	7,310	149	609.2
	30-acre	12	7,600	149	633.3
	Total or average	50	31,195		623.9
1917	100-acre	10	7,735	155	773.5
	70-acre	10	7,800	155	780.0
	50-acre	10	7,700	155	770.0
	30-acre	10	7,730	114	773.0
	Total or average	40	30,965		774.1
1918	100-acre	14	7,090	157	506.4
	70-acre	14	7,070	157	505.0
	50-acre	14	6,945	157	496.0
	30-acre	14	6,970	107	498.0
	Rotation 70-acre	14	7,020	157	501.4
	Total or average	70	35,095		501.4

It will be seen by Table 1 that 7,000 to 7,500 pounds weight is our approximate standard, or a 700- to 750-pound steer is our approved unit weight when the cattle are placed in the pasture in the spring. In all cases where more than 10 head of steers to the pasture were used some yearlings have been included.

In this discussion thruout I will refer to the cattle on the basis of 10 head of 2-year-old steers per pasture, for convenience in making comparisons. In some cases 14 head of yearling cattle have been used instead of 10 head of 2-year-olds.

The reserve pasture has served a very useful purpose in providing grass for the lot of cattle given 3 acres per 2-year-old steer after their supply of grass was exhausted and also by supplying substitutes when a trial animal was disabled.

Quadrats 20 by 300 feet in area were fenced off early in 1915 in the 30-acre pasture, which it was anticipated would be overgrazed, and in the 100-acre pasture, which it was expected would be undergrazed during the trial. These were isolated for the purpose of making floral population studies. Beginning in 1916, perquadrats 4 meters square have been opened for grazing each year, and a perquadrat of similar size has been taken in from the body of the pasture. If a population study can be made each year for ten years as planned, at the end of that time data will be secured on areas that have been grazed from one to ten years. Quadrats are established at the points marked + on the pasture diagram, these having been laid out by surveying from known points. On these quadrats the grass species population is counted and mapped at intervals during the trial. About 175 different species of plants were collected by Mr. Sarvis during the season of 1915 and made into a herbarium at the Federal station at Mandan for purposes of comparison. A view of a section of the pasture in 1915, when the trial was begun, is shown in Plate 3, figure 1.

Following is a list giving the dominant, primary, and secondary species in the pastures:

Dominant species, *Bouteloua gracilis* (blue grama) and *Stipa comata* (western needle grass).

Primary species, *Stipa viridula* (feather bunchgrass), *Andropogon scoparius* (little bluestem), *Andropogon furcatus* (big bluestem), *Stipa spartea* (porcupine grass), and *Koeleria cristata* (prairie Junegrass).

Secondary species, *Aristida longiseta* (wiregrass), *Agropyron smithii* (western wheatgrass), *Calamovilfa longifolia* (sandgrass), *Agropyron caninum* (bearded wheatgrass), *Bouteloua curtipendula* (tall grama), *Bulbilis dactyloides* (buffalo grass), *Poa palustris* (*false redtop*), *Agropyron tenerum* (slender wheatgrass), *Elymus canadensis* (Canadian wild rye), and *Sporobolus brevifolius* (prairie rushgrass).

A number of species occur that are not abundant enough to enter into consideration as supplying or hindering pasture.

Blue grama (*Bouteloua gracilis*), typical of the short-grass region, and western needle grass (*Stipa comata*) are the predominating species. Needle grass is representative of the long grass or prairie formation. Apparently the grass land occupants of this pasture would in majority belong to this formation. The blue grama and western needle grass association on these pastures is dominated by the blue grama, which covers approximately twice as much ground surface as the needle grass.

The blue grama from the standpoint of grazing ranks above the needle grass. It stands trampling well and responds to light rains that would not be sufficient to stimulate growth in most other grasses. It is greatly relished by stock. Needle grass furnishes early grazing in the spring and regularly to the time when the needles are formed. When the needles are on, the stock avoid it for a couple of weeks until the needles drop, after which it is again readily eaten for the remainder of the season.

One of the most relished grasses is the big bluestem (*Andropogon furcatus*). It is not plentiful enough to supply much forage, occurring mostly in the ravines. It makes abundant growth, stands drouth well, and recovers rapidly from grazing. It is always grazed closely by the stock and hence has little chance to spread. On these pastures this grass was eaten almost exclusively when the stock were first turned in until it was closely grazed and the new growth has been fed down as fast as it has appeared during the four years of the trial.

Western wheatgrass (*Agropyron smithii*) is one of the best range grasses, but occurs too sparsely in the pastures to be of much consequence. Three grasses of doubtful value and little relished are little bluestem (*Andropogon scoparius*), wiregrass (*Aristida longiseta*), and prairie rushgrass (*Sporobolus brevifolius*). All three furnish some acceptable grazing when young, but soon become harsh and woody. These three are bunch grasses and form dense tussocks. When the 30- and 50-acre pastures grew short the steers left these grasses standing, but when hunger pressed them the tufts were grazed close to the ground. Bunches of wiregrass left by the cattle are shown in Plate 4, figure 1. In figure 2 a portion of the 30-acre pasture is shown in which all grasses are grazed close. Plate 5 shows other views of the pastures.

Plants other than grasses also occur in small percentage and are

allowed to grow by the grazing steers except when necessity forces the cattle to eat them. Their chief importance is that they occupy ground which otherwise might furnish grass and there is a possibility of their affecting the flavor of the flesh of animals when eaten. Most of these plants are eaten to some extent, in the pasture not overstocked, in some stage of their growth.

Following is a list of the plants other than grasses which occur on these pastures.

Dominant species.

Carex filifolia (nigger-wool sedge). It is estimated that this plant covers from 1 to 2 percent of the surface of the ground.

Carex heliophia (sedge). This plant covers less than 1 percent, but a larger area than any of the following.

Primary species.

The following list of primary species is arranged in their order of abundance as based upon actual counts made of 100 quadrats

	Percent
Artemisia gnaphaloides (wild sage)	24.0
Solidago rigida (goldenrod)	17.4
Artemisia canadensis (wild sage)	12.5
Psoralea argophylla (silver-leaved psoralea)	12.2
Artemisia frigida (wild sage)	11.6
Echinacea angustifolia (purple coneflower)	8.7
Polygala alba (white milkwort)	6.6
Ratibida columnaris (yellow coneflower)	4.3

Secondary species.

Lacinaria punctata,
Oxytropis lambertii (loco weed),
Hedomia hispida,
Salsola pestifer (Russian thistle),
Comandria pallida.
Senecio plattensis,
Petalostemon purpureum,
Aster multiflorus,
Sideranthus spinulosus,
Lactuca pulchella,
Vicia sparsifolia,
Malvastrum coccineum,
Cherrinia aspera,
Petalostemon candidum.

The percentages of the vegetation removed by the cattle from the various pastures are shown in Table 2.

TABLE 2.—*Percentage of vegetation grazed from each pasture yearly.*

Year.	Pasture.			
	100-acre.	70-acre.	50-acre.	30-acre.
1916	30	50	70	95
1917	40	60	90	100
1918	55	75	100	100

In the 100- and in the 70-acre pastures the grazing is more patchy than in the 50- and 30-acre ones and was noticeably so from the year 1916 forward.

The pasture ground cover was determined by measurement and count and was found to be about 60 percent. In other words, 60 acres in 100 are covered with vegetation of some kind on these pastures. The grass cover, however, would be called heavy or dense range grass by stockmen.

Two hundred and thirteen head of cattle have been used in this trial during the four years that it has been under way. The fact that they have gained an average of 1.86 pounds per head per day during the time they have been grazed is evidence that they have been thrifty and reasonably well-bred stock.

I find few data covering the carrying capacity of domestic pastures which throw light on gains of cattle or carrying capacity of full-season grazing. Morrow of the Illinois station in the early eighties (1880, 1882, 1883, and 1885) carried on grazing experiments with beef steers. In his experiments, 35 steers pastured for 154 days showed an average gain per day of 1.9 pounds. Morrow does not describe his pasture nor his steers, but I feel safe in assuming that he used grade beef cattle and that he grazed them on the standard domestic or tame grass pastures of Illinois.

Hunt of the Virginia station in the December, 1918, issue of *The Field* reports that he pastured steers in 1915, 1916, and 1917, presumably on bluegrass pasture. He reports that 15 steers averaging 1,100 pounds pastured for 135 days showed an average gain of 2.04 pounds per day. Hunt does not give the area of pasture supplied per steer. He used Shorthorn and Hereford grades in his trial.

Carrier and Oakley at the Virginia station in 1909, 1910, and 1912 carried on a pasturing trial, in which 30 steers pastured for 151 days averaged 2 acres per head and gained an average of 1.52 pounds per day. These steers were on a 12-year-old bluegrass pasture. Carrier and Oakley do not describe their cattle more than to say that 2-year-old steers were used in 1909 and yearlings the other two years.

The Mandan results give an average of 1.86 pounds per head per day and make a reasonably good comparison with the Illinois and Virginia station gains. They may, I believe, be called standard for range-grazed cattle.

Shorthorn, Angus, and Hereford grade and crossbred cattle have been used in the Mandan trial. The majority have been range-bred stock, altho a few farm-bred cattle have been used. Except that

FIG. 1. View showing condition of the pasture in 1915 when the trial was begun.

FIG. 2. Type of cattle used in 1915.

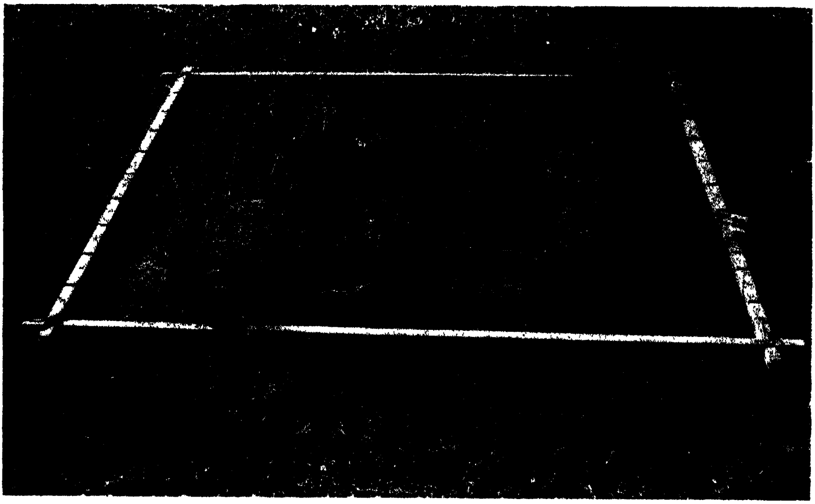

FIG. 1. Close view of the Aristida bunches left by cattle. Note close grazing around them. Also compare with Plate 4, figure 2, where scant pasture forced the cattle to eat this forage plant.

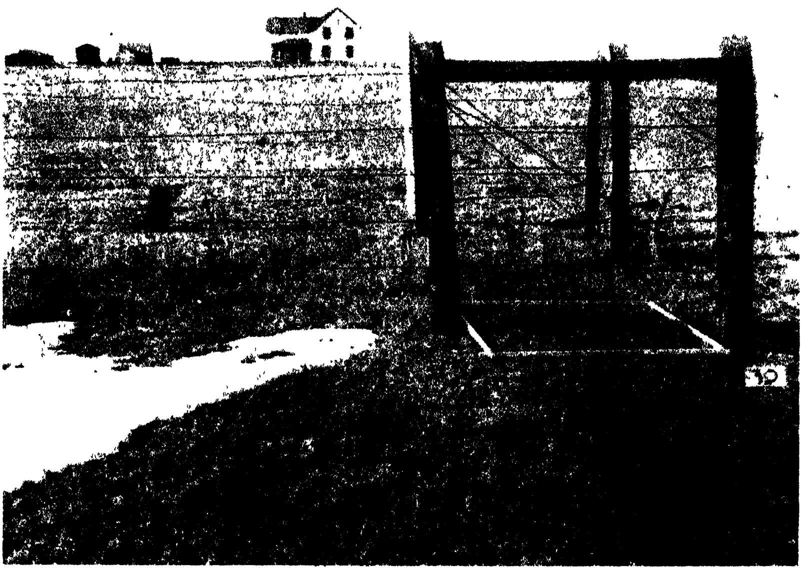

FIG. 2. Area in foreground of 3-acre-per-steer pasture is quadrat opened to grazing in 1918. Background shows completeness of grazing, or 100 percent. Note how closely the 3-acre-per-steer cattle grazed a heavy growth the first season it was opened to them. Compare Plate 5, figure 1, where a similar area was opened to the 10-acre-per-steer lot of cattle.

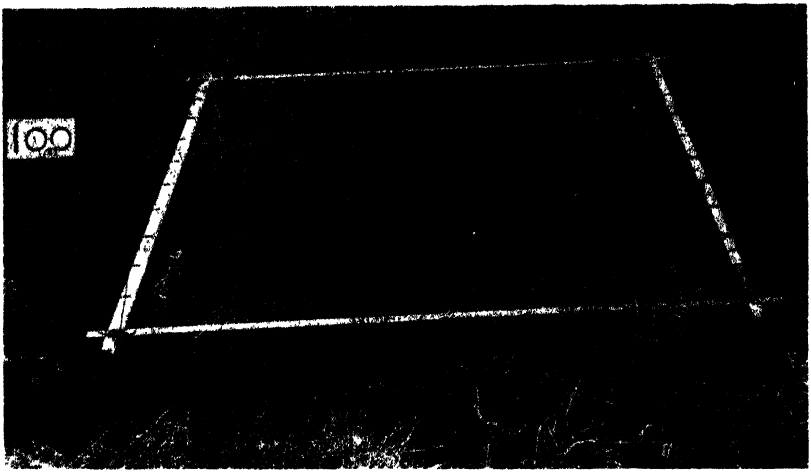

FIG. 1. View of area in 10-acre-to-the-steer pasture opened to cattle in the spring of 1918. Note how little grazed it is compared with Plate 4, figure 2, the 3-acre-to-the-steer pasture opened to grazing at the same time

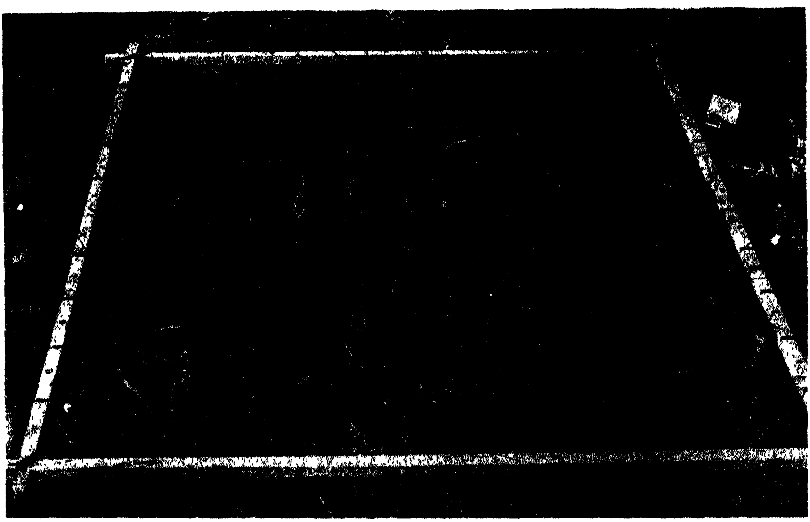

FIG. 2. View of area closed in 1917. Note the thickening of the cover on this 3-acre-to-the-steer pasture with two years' rest period.

they were wild and hard to handle on that account range stock are more satisfactory than domestic cattle. A group of the cattle used in 1915 are shown in Plate 3, figure 2.

Two-year-old steers have been secured in so far as that has been possible, but for two seasons a number of yearlings had to be substituted. In 1918 some heifers were taken. Extra numbers are used when younger cattle are substituted so that the live weight per pasture has been nearly constant at from 7,000 to 7,500 pounds.

The five pastures already described have been pastured by groups of cattle carefully divided into bunches so as to be uniform in type, age, weight, and general character at the beginning of the grazing season. Approximately the same live weight has been placed in each pasture lot at the opening of the pasturing season each year. Beginning with 1916 and from that season on four pastures have been stocked with the same number and approximate weight of cattle or at the rate of 3, 5, 7, and 10 acres to the 2-year-old steer. At the close of the second year (1917) of separate pasture grazing the 3-acre-to-the-steer pasture was exhausted as shown by a shrinkage in weight of the cattle.

TABLE 3.—*Results of grazing experiments with steers in 1918 at Mandan (2 two-year-olds and 12 yearlings in each pasture).*

30-ACRE PASTURE.

Date of weighing.	Length of period.	Total weight.	Average weight.	Gain or loss per lot.	Average gain or loss per head.	Gain per acre.	Average gain or loss per day.
	Days.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
May 17		6,970	498				
May 31	15	7,390	528	420	30.0		2.0
June 30	30	8,855	633	1,465	104.7		3.5
July 30	30	9,050	646	195	14.0		0.5
Aug. 29[a]	30	9,150	654	100	7.1		0.2
Total	105			2,180	155.8	72.7	1.5

50-ACRE PASTURE.

Date of weighing.	Length of period.	Total weight.	Average weight.	Gain or loss per lot.	Average gain or loss per head.	Gain per acre.	Average gain or loss per day.
May 17		6,945	496				
May 31	15	7,715	551	770	55.0		3.7
June 30	30	9,020	644	1,305	93.2		3.1
July 30	30	9,760	697	740	52.9		1.8
Aug. 29	30	10,280	734	520	37.1		1.2
Sept. 28	30	10,970	784	690	49.3		1.6
Oct. 20	22	10,715	765	−255	−18.2		−.9
Total	157			3,770	269.3	75.4	1.8

TABLE 3.—*Results of grazing experiments.*—Continued.

Date of weighing.	Length of period.	Total weight.	Average weight.	Gain or loss per lot.	Average gain or loss per head.	Gain per acre.	Average gain or loss per day.
	Days.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
70-ACRE PASTURE.							
May 17		7,070	505				
May 31	15	7,905	565	835	59.7		4.0
June 30	30	9,380[b]	670	1,475	105.4		3.5
July 30	30	10,035	717	805	57.5		1.9
Aug. 29	30	10,500	750	465	33.2		1.1
Sept. 28	30	11,190	799	690	49.3		1.6
Oct. 20	22	11,370	812	180	12.9		0.6
Total	157			4,450	318.0	63.6	2.0
100-ACRE PASTURE.							
May 17		7,090	506				
May 31	15	7,645	546	555	39.6		2.2
June 30	30	8,580	613	935	66.8		2.4
July 30	30	9,620	687	1,040	74.3		2.5
Aug. 29	30	10,490	749	870	62.1		2.1
Sept. 28	30	11,255	804	765	54.6		1.8
Oct. 20	22	11,390	814	135	9.7		.5
Total	157			4,300	307.1	43.0	1.9
ROTATION PASTURE.							
May 17		7,020	501				
May 31	15	7,800	557	780	55.7		3.7
June 30	30	8,885	635	1,085	77.5		2.6
July 30	30	9,375	670	490	35.0		1.2
Aug. 29	30	10,120	723	745	53.2		1.7
Sept. 28	30	10,690	764	570	40.7		1.4
Oct. 20	22	10,710	765	20	1.4		.1
Total	157			3,690	263.6	52.7	1.7

[a] Cattle removed from pasture. This lot of cattle showed a loss in weight of 240 pounds during the last ten days of August, or at the rate of 1.7 pounds per head per day.

[b] Weight after substitution, 9,230 pounds.

In the third year the 3-acre-to-the-steer pasture was exhausted August 30, or at the end of 106 days, and the cattle lost weight regularly after that time until removed from the pasture. On September 30, at the end of 137 days, the 5-acres-to-the-steer pasture was exhausted and the cattle began losing weight rapidly. Seven acres to the steer seems to be carrying the cattle satisfactorily. A rotation pasture supplying 7 acres to the steer was started in 1918. This pasture lies adjacent to the original 70-acre pasture and is fenced into

three equal parts consisting of 23⅓ acres each. The cattle were pastured on A, B, and C sections of it respectively during the first, middle, and latter portions of the grazing season during 1918. In 1919 they will be pastured first on B, second on C, and third on A. In 1920 they will be pastured first on C, second on A, and third on B, and continue in a similar repeating rotative manner thruout the trial. Table 3 gives the detailed results for the cattle in the third year of the trial, 1918.

TABLE 4.—*Summary of results of grazing experiment at Mandan in 1918 with 2 two-year- olds and 12 head of yearling cattle in each pasture.*

Data.	Pasture				
	100 acres.	70 acres	50 acres.	30 acres	Rotation, 70 acres
Total weight May 16, pounds	7,090	7,070	6,945	6,970	7,020
Total weight Oct. 20, pounds	11,390	11,370	10,715	9,150[a]	10,710
Average weight May 16, pounds	506	505	496	498	501
Average weight Oct. 20, pounds	814	812	765	654[a]	765
Gain per pasture in 158 days, pounds	4,300	4,450	3,770	2,180[a]	3,690
Average gain per head, pounds	307	318	269	156[a]	264
Average gain per day, pounds	1.9	2.0	1.7	1.4[a]	1.7
Gain per acre, pounds	43.0	63.6	75.4	72.7	52.7

[a] Weight September 1 when 30-acre pasture was exhausted.

Table 5, which gives a summary of the pasturing results for three years, shows similar altho more marked results than those for 1918 as the per acre gain from heavy and light pasturing.

In the summary table for 1918 it will be seen that the added weight or gain per acre of pasture decreases with the acreage of grass supplied per steer. Three acres to the steer in 1918 gave 72.69 pounds of gain per acre or 69 percent more gain per acre than 10 acres to the steer, despite the fact that it had been pastured to exhaustion the previous year and lasted only 106 days, while 10 acres to the steer was grazed 157 days. The increases per acre of grass land were in reverse ratio to the acreage supplied per head.

Carrier and Oakley report results from trials on an old bluegrass pasture as follows:

3 steers grazed 151 days on 2½ acres per steer gained 112 pounds per acre.
6 steers grazed 151 days on 1¼ acres per steer gained 198 pounds per acre.

These gains per acre are naturally much heavier than those secured under range conditions, but show a similar spread in the total gain per acre on heavy and light pasturing. It is interesting to note also

TABLE 5.—*Average gain per head for the entire pasturage period, gain per head per day, and gain per head per acre in grazing experiments at Mandan in 1916, 1917, and 1918.*

Year.	Number of days.	Pasture. 100-acre.	70-acre.	50-acre.	30-acre	70-acre rotation.
		AVERAGE GAIN PER HEAD.				
1916	149	271.1	324.9	321.2	271.7	
1917	155	241.5	213.0	227.0	124.0[a]	
1918	158	307.1	318.0	269.3	155.8[b]	263.6
Average		273.2	285.3	272.5	183.5	
		AVERAGE GAIN PER DAY.				
1916	149	1.82	2.18	2.16	1.82	
1917	155	1.37	1.46	1.46	1.08	
1918	158	1.94	2.00	1.72	1.40	1.70
Average		1.71	1.88	1.78	1.43	
		GAIN IN WEIGHT OF CATTLE PRODUCED PER ACRE.				
1916	149	37.97	55.71	77.10	108.66	
1917	155	24.15	30.43	45.40	66.66	
1918	158	43.00	63.59	75.40	72.69	52.71
Average		35.04	49.91	65.96	82.67	

[a] Pasture exhausted September 1 after 106 days grazing.
[b] Pasture exhausted September 18 after 123 days grazing.

that Virginia bluegrass sod improved from heavy grazing while the lightly grazed pasture grew weedy. These experimenters report no advantage from rotation pasturing.

The rotation pasture (7 acres to the steer) at Mandan gave only five-sixths the gain obtained from the nonrotated 7-acre-to-the-steer pasture. Five steers from this pasture broke out and were returned after covering 30 miles. They were gaunt and doubtless shrunk considerably during that time. They were turned in on section C of their pasture September 1 and were out September 11 to 14. The grazing was particularly good in division C at that time, but the cattle were nervous and restless when returned. This difference seems to me, however, to be chiefly chargeable to the fact that the rotation 70-acre pasture had not been grazed down in several years and contained much dead grass, which is either not relished, so that the cattle do not eat heavily of it, or is not nutritious and fails to give good

gains when consumed. The other 7-acre-to-the-steer pasture had been grazed regularly for three years and hence was reasonably well pastured down. Further evidence that the fresh grass of early spring gives much more rapid gains than the drier grass of the later season is shown by Table 6.

TABLE 6.—*Gains made per day by grazing periods, 1915 to 1918.*

Period.	Number of steers.	Inclusive dates.	Length of period, days.	Gains per day per head, pounds
Season	53	July 17 to Nov. 3, 1915	109	1.8
1st	50	June 1 to July 17, 1916	47	3.4
2d	50	July 18 to Sept. 13, 1916	58	2.1
3d	50	Sept. 13 to Oct. 13, 1916	30	0.8
4th	50	Oct. 13 to Oct. 27, 1916	14	−0.9
1st	40	May 26 to June 30, 1917	35	3.6
2d	40	July 1 to Aug. 29, 1917	60	1.5
3d	40	Aug. 29 to Sept. 28, 1917	30	0.7
4th	40	Sept. 28 to Oct. 29, 1917	30	−0.6
1st	70	May 16 to July 1, 1918	46	3.0
2d	70	July 1 to Aug 30, 1918	61	1.4
3d	56	Aug. 30 to Sept 30, 1918	30	1.6
4th	56	Sept. 30 to Oct 20, 1918	20	.1

Summary by periods for 3 years, 1916–1918.

1st	160		44	3.26
2d	160		60	1.64
3d	146		30	1.07
4th	146		22	.47

Summary entire season for 4 years, 1915–1918.

213 steers 140 days, average gain per day 1.86

It will be noted that for the three years the average gain per day for the first 44 days is double that of the next 60 days, while the gain for the 30 days following the first 104 days of the season is only 1.07 pounds, or less than one-third that of the first 44 days. During the last 22 days of the grazing season in the month of October the cattle sustain a loss of 0.47 pound in weight per day.

The average gain per day secured in a 3-year trial when grazing 44, 104, 134, and 140 days respectively is shown below. This is a summarized comparison of the total gains which may be expected at different dates in the full season.

Period.	Gain per day, pounds.
First period, 160 steers, 44 days	3.26
First and second periods, 160 steers, 104 days	2.33
First, second, and third periods, 157 steers, 134 days	2.06
First, second, third, and fourth periods, 213 steers, 140 days	1.86

Cattle as thin as stocker steers are in the spring naturally gain more rapidly than they do later, but I do not believe that the large and consistent gains here shown can be accounted for in that way.

These results do not bear out the theory that amide substances found in succulent plants have less value in producing gains in live stock than the protein substance found in more mature plant growth.

Four years is too short a time to give conclusive results from a grazing trial, but the evidence seems reasonably conclusive that less than 7 acres to the 2-year-old steer will not carry and that the principal gains are made by cattle during the early part of the season. Also, that late season grazing is done without gains or at an actual loss in weight. They also indicate that the number of acres supplied per steer in practice will depend upon the farm management questions of the cost of supplementing pastures and the price of land used for grazing, as heavy early season pasturing gives maximum per acre yields.

ON THE BLOOMING AND FERTILIZATION OF WHEAT FLOWERS.[1]

C. E. LEIGHTY AND T. B. HUTCHESON.

The observations and experiments on wheat flowers reported in this paper were made at the Minnesota Agricultural Experiment Station, St. Paul, Minn., and at the Arlington Experiment Farm, Rosslyn, Virginia. Part 1 deals with the time of blooming of flowers of several varieties of wheat. Part 2 deals with the fertilization of emasculated wheat flowers that takes place when these are left unprotected from foreign pollination.

1. TIME OF BLOOMING OF WHEAT FLOWERS

In the observations made on the time of blooming of wheat flowers, heads of wheat of several varieties were marked before they had begun to bloom and diagrams of these heads were made. Heads in the same stage of development were chosen, so far as possible, on which it was expected that blooming would soon begin. These heads were then examined at least three times a day, usually at 7 a.m., 12 m., and 5 or 6 p.m., some variation from these hours being noted later. At each examination any flowers having bloomed since the last examination were so recorded on the diagram. A flower was considered as having bloomed from the time the glumes had opened appreciably.

The process of blooming of a wheat flower is very rapid. From the time that they first begin to open the glumes may be fully open in less than 1 minute; the anthers may be extruded and emptied of pollen within 2 or 3 minutes; the glumes may be half closed within 5 minutes, loosely closed within 10 minutes, and tightly closed at the end of 15 or 20 minutes. The entire process, from the time that the first opening movement of the glumes can be observed until they are again tightly closed, seldom requires more than 20 minutes.

The period from 6 p.m. to 7 a.m. is hereafter referred to as "night," altho several hours of daylight are included. It was not determined whether the blooming takes place only in these hours of

[1] Joint contribution from the Office of Cereal Investigations, United States Department of Agriculture, Washington, D. C., and the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn. Received for publication January 24, 1919.

light or whether is occurs partially or wholly in darkness. It was impracticable under the conditions of experiment both in Minnesota and at Arlington Farm to make the data thus complete.

OBSERVATIONS ON TIME OF BLOOMING AT THE MINNESOTA EXPERIMENT STATION.

In Tables 1, 2, and 3 the results of the observations on time of blooming made at the Minnesota Agricultural Experiment Station are shown, Table 1 setting forth those made on the common spring wheats.

TABLE 1.—*Numbers of flowers per head and per variety of common spring wheat blooming between stated hours within stated periods in July, 1914, at the Minnesota Agricultural Experiment Station.*

Head No.	Flowers blooming between			Period of blooming.
	6 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	
"VELVET CHAFF."				
1	18	22	3	July 2–4
2	29	21	0	July 2–4
3	24	14	4	July 1–4
4	24	22	2	July 2–4
5	20	10	5	July 2–4
Total	115	89	14	
HAYNES BLUESTEM.				
1	21	9	8	July 6–8
2	34	15	3	July 6–8
3	28	9	5	July 6–8
4	28	10	4	July 6–8
5	27	10	3	July 6–8
Total	138	53	23	
GLYNDON FIFE.				
1	23	9	5	July 1–3
2	15	7	10	July 2–4
3	15	2	7	July 2–4
4	15	6	4	July 3–4
5	9	0	5	July 3–4
Total	77	24	31	
Total three varieties.......	330	166	68	

It may be noted in these common spring varieties that a greater part of the blooming takes place between 6 p.m. and 7 a.m. The proportion is 330 at night to 234 in the day. In "Velvet Chaff" and

Bluestem most of the day blooming is in the forenoon, 89 and 53 flowers respectively of these two varieties blooming in this period, while 14 and 23 respectively bloomed in the afternoon. In Glyndon Fife there is very little difference between the amount of forenoon and afternoon blooming, there being 24 before noon and 31 after noon. The night and total day bloomings for the three varieties are: "Velvet Chaff," 115 night, 103 day; Haynes Bluestem, 138 night, 76 day; Glyndon Fife, 77 night, 56 day.

In Table 2 are shown the observations made on two varieties of durum wheat.

TABLE 2.—*Numbers of flowers per head and per variety of durum wheat blooming between stated hours of the day within stated periods in June and July, 1914, at the Minnesota Agricultural Experiment Station.*

KUBANKA.

Head No.	Flowers blooming between			Period of blooming.
	6 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	
1	27	8	2	June 27–July 3
2	12	19	8	June 27–July 3
3	20	13	3	June 27–July 2
4	18	9	9	June 29–July 3
Total......	77	49	22	

ARNAUTKA.

Head No.	6 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	Period of blooming.
1	25	16	0	June 28–July 2
2	30	16	0	June 28–July 2
3	33	15	10	June 29–July 3
4	19	11	7	June 29–July 3
5	27	10	5	June 30–July 4
Total.........	134	68	22	
Total two varieties.........	211	117	44	

These results on the durum wheats show for both varieties a greater amount of blooming at night. For Kubanka the difference is not large, being 77 at night and 71 in the day, while for Arnautka about three-fifths of the blooming takes place at night, there being 134 at night to 90 in the day. Both varieties show most of their day blooming in the forenoon, the forenoon and afternoon bloomings being 49 and 22 for Kubanka and 68 and 22 for Arnautka.

In Table 3 are shown the observations made on two varieties of winter wheat.

TABLE 3.—*Number of flowers per head and per variety of winter wheat blooming between stated hours within stated periods in June, 1914, at the Minnesota Agricultural Experiment Station.*

KHARKOV.

Head No.	Flowers blooming between			Period of blooming.
	6 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	
1	25	17	23	June 18–23
2	29	11	13	June 19–24
3	33	16	29	June 18–24
4	36	22	20	June 19–24
5	42	18	18	June 19–24
Total.........	165	84	103	

TURKEY.

Head No.	6 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	Period of blooming.
1	14	14	17	June 20–25
2	22	8	11	June 19–24
3	12	16	13	June 19–24
4	13	16	11	June 19–24
5	18	16	11	June 18–24
Total.........	79	70	63	
Total two varieties.........	244	154	166	

The results for the Kharkov variety are 165 night bloomings and 187 day; for the Turkey variety, 79 night bloomings and 133 day. The forenoon and afternoon bloomings are 84 and 103 respectively for Kharkov, and 70 and 63 for Turkey. In both of the winter varieties a majority of the flowers open in the daytime and there is no consistent preponderance of either forenoon or afternoon blooming, the totals for the two varieties being 154 forenoon and 166 afternoon. The total of all flowers of both varieties observed is slightly greater for the afternoon than for the morning. The observations on the winter wheats were made necessarily on different days from those on the spring wheats, as the blooming time of winter wheats is earlier in the season than that of spring wheats. Differences in the climatic conditions of the two periods may have had some influence on the time of blooming of the flowers.

There were under observation at the Minnesota Agricultural Experiment Station 1,500 flowers in all. Seven varieties belonging to three distinct types of wheat were represented. Of the flowers on which notes were taken 785 bloomed at night (that is, between 5 p.m. and 7 a.m.), while 715 bloomed in the day (that is, between 7 a.m.

and 6 p.m.). Of those blooming during the day, 437 bloomed between 7 a.m. and 12 noon, while 278 bloomed between 12 noon and 6 p.m.

A summary of Tables 1, 2 and 3 is made in Table 4.

TABLE 4.—*Number of flowers of different types and varieties of wheat blooming during different periods at the Minnesota Agricultural Experiment Station.*

Type and variety.	Total number of flowers under observation.	Number of flowers blooming between—			
		5 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 6 p. m.	Total, day.
Common spring:					
"Velvet Chaff"	218	115	89	14	103
Haynes Bluestem	214	138	53	23	76
Glyndon Fife	132	77	24	31	55
Total	564	330	166	68	234
Durum:					
Kubanka	148	77	49	22	71
Arnautka	224	134	68	22	90
Total	372	211	117	44	161
Winter:					
Kharkov	352	165	84	103	187
Turkey	212	79	70	63	133
Total	564	244	154	166	320
Grand total	1,500	785	437	278	715

It thus appears that under the conditions existing when and where these observations were made, about half of the blooming of wheat flowers occurred between 7 a.m. and 6 p.m. The other half occurred some time between 6 p.m. and 7 a.m., but it is not known whether blooming took place during the darkness of night or in the hours of twilight and of light before and after observations were made. It is probable, however, that much of this blooming occurred in the early morning about the time of sunrise, which was about 2½ hours before the first observations were made. This conclusion is supported by the statement of Hays:[2] "The floret (of wheat) usually opens about dawn, and closes again within an hour."

OBSERVATIONS ON TIME OF BLOOMING AT ARLINGTON FARM, ROSSLYN, VA.

Observations on time of blooming of wheat flowers at Arlington Experiment Farm, Rosslyn, Va., here reported were made on seven

[2] Hays, Willet M. Plant breeding. U. S. Dept. Agr., Div. Veg. Phys. & Path. Bul. 29, p. 50. 1901.

varieties of wheat. These included three varieties of the soft red winter type, one variety of the soft white winter type, one variety of the hard red winter type, and two varieties of the hard red spring type. The varieties of the hard red spring type, owing to climatic conditions in this section unsuited to spring-sown wheats, were here sown in the fall, at the regular time for sowing winter wheats. Classification, names, and descriptions of the varieties used follow.

Soft red winter type:
  Dietz, bearded, glabrous white chaff, soft red kernels.
  Fultz, beardless, glabrous white chaff, soft red kernels.
  Mealy, beardless, pubescent white chaff, soft red kernels.

Soft white winter type:
  Giant Squarehead, bearded, glabrous white chaff, soft white or amber kernels.

Hard red winter type:
  Turkey, bearded, glabrous white chaff, hard red kernels.

Hard red spring type (grown as winter):
  Bluestem (Minn. No. 169), beardless, pubescent white chaff, hard red kernels.
  Fife (Minn. No. 163), beardless, glabrous white chaff, hard red kernels.

The results of the observations made at Arlington Farm are recorded in Tables 5 and 6.

TABLE 5.—*Number of flowers per head and per variety of different types of wheat blooming between stated hours within stated periods in May and June, 1914, at Arlington Farm.*[a]

DIETZ (SELECTION NO. 13356).

Total flowers per head.	Flowers blooming between 5 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 5 p. m.	Total day blooming.	Period of blooming per head (1914).	Duration of blooming, hours.
51	28	4	19	23	5 p. m. May 26 to 10 a. m. May 30	89
48	18	14	16	30	5 p. m. May 26 to 4 p. m. May 29	71
51	26	11	14	25	5 p. m. May 26 to 10 a. m. May 30	89
53	20	21	12	33	4 p. m. May 27 to 10 a. m. May 30	66
44	19	9	16	25	5 p. m. May 26 to 7 a. m. May 29	62
247	111	59	77	136		75.4

FULTZ (SELECTION NO. 13360).

Total flowers per head.	5 p. m. and 7 a. m.	7 a. m. and 12 m.	12 m. and 5 p. m.	Total day blooming.	Period of blooming per head (1914).	Duration of blooming, hours.
56	28	13	15	28	5 p. m. May 26 to 10 a. m. May 30	89
53	31	5	17	22	5 p. m. May 26 to 7 a. m. May 29	62
59	26	10	23	33	5 p. m. May 26 to 5 p. m. May 29	72
51	33	8	10	18	5 p. m. May 26 to 10 a. m. May 30	89
36	21	6	9	15	4 p. m. May 27 to 10 a. m. May 30	66
255	139	42	74	116		75.6

TABLE 5.—*Number of flowers per head and per variety, etc.*—Continued.

MEALY (SELECTION NO. 13377).

Total flowers per head.	Flowers blooming between 5 p.m. and 7 a.m.	7 a.m. and 12 m.	12 m. and 5 p.m.	Total day blooming.	Period of blooming per head (1914).	Duration of blooming, hours.
52	21	14	17	31	5 p.m. May 26 to 11 a.m. May 29	66
38	16	7	15	22	11 a.m. May 27 to 3 p.m. May 29	52
54	23	15	16	31	4 p.m. May 27 to 10 a.m. May 30	66
61	18	18	25	43	7 a.m. May 27 to 10 a.m. May 30	75
55	27	11	17	28	4 p.m. May 26 to 10 a.m. May 30	90
260	105	65	90	155		69.8

GIANT SQUAREHEAD (SELECTION NO. 13367–8).

32	14	11	7	18	5 p.m. May 26 to 9 a.m. May 29	64
30	13	7	10	17	5 p.m. May 26 to 3 p.m. May 29	70
28	11	5	12	17	5 p.m. May 26 to 7 a.m. May 29	62
30	14	6	10	16	11 a.m. May 27 to 3 p.m. May 29	52
30	12	8	10	18	9 a.m. May 27 to 9 a.m. May 29	48
150	64	37	49	86		59.2

TURKEY (SELECTION NO. 13389).

45	22	11	12	23	4 p.m. May 27 to 10 a.m. May 30	66
36	20	7	9	16	7 a.m. May 28 to 10 a.m. May 30	51
43	20	9	14	23	4 p.m. May 27 to 10 a.m. May 30	66
55	24	14	17	31	8 a.m. May 27 to 10 a.m. May 30	74
57	27	9	21	30	5 p.m. May 26 to 10 a.m. May 30	89
236	113	50	73	123		69.2

BLUESTEM (MINNESOTA NO. 169).[b]

36	20	10	6	16	2 p.m. June 1 to 12 m. June 4	70
27	18	4	5	9	5 p.m. June 1 to 7 a.m. June 5	86
28	19	4	5	9	5 p.m. June 1 to 7 a.m. June 5	86
24	6	6	12	18	5 p.m. June 1 to 12 m. June 4	67
32	8	7	17	24	2 p.m. June 1 to 12 m. June 4	70
147	71	31	45	76		75.8

[a] Some slight inaccuracies exist in Table 5, as can be seen by comparison with Tables 7 and 8. The flowers blooming in the observation period from 11 a.m. to 3 p.m. on May 27, and 11 a.m. to 4 p.m. on June 2 are included in this summary as blooming between 12 m. and 5 p.m. Again on May 28 the final observation was made at 7 p.m., and on May 30 at 6 p.m. and not at 5 p.m., while the morning observation on May 30, when the blooming period was nearly done, was at 10 a.m. The afternoon period is slightly favored, but the errors, small in any case, are believed to at least partially counterbalance each other.

TABLE 5.—*Number of flowers per head and per variety, etc.*—Concluded.

FIFE (MINNESOTA NO. 163).[b]

Total flowers per head	Flowers blooming between 5 p.m and 7 a m.	7 a. m. and 12 m.	12 m and 5 p m	Total day blooming.	Period of blooming per head (1914).	Duration of blooming, hours.
42	24	11	7	18	5 p. m. June 1 to 5 p. m. June 5	96
36	16	10	10	20	5 p. m. June 1 to 5 p. m. June 5	96
40	22	7	11	18	12 m. June 2 to 5 p. m. June 5	77
41	24	10	7	17	5 p. m. June 1 to 5 p. m. June 5	96
23	18	5		5	5 p. m. June 3 to 5 p. m. June 5	48
182	104	43	35	78		82.6

[b] Morning observation on these varieties was made at 8 a.m., so that night period is from 5 p.m. to 8 a.m. and day period from 8 a.m. to 5 p.m.

TABLE 6.—*Total number of flowers under observation, flowers blooming at night, in the forenoon and afternoon, in the entire day, and average duration and range of blooming period per head of the seven varieties of four types of wheat at Arlington Farm, May and June, 1914.*

Type and variety	Total flowers under observation	Flowers blooming between 5 p. m and 7 a m.[a]	Flowers blooming during day between— 7 a. m.[a] and 12 m.	12 m and 5 p m.	Total day.	Average duration of blooming, hours.	Range of blooming period for different heads, hours.
Soft red winter:							
Dietz	247	111	59	77	136	75.4	62–89
Fultz	255	139	42	74	116	75.6	62–89
Mealy	260	105	65	90	155	69.8	52–90
Total or average for type	762	355	166	241	407	73.6	
Soft white winter:							
Giant Squarehead	150	64	37	49	86	59.2	48–70
Hard red winter:							
Turkey	236	113	50	73	123	69.2	51–89
Total or average for winter type	1,148	532	253	363	616	69.8	
Hard red spring:							
Bluestem	147	71	31	45	76	75.8	67–86
Fife	182	104	43	35	78	82.6	48–96
Total or average for spring type	329	175	74	80	154	79.2	
Grand total or average	1,477	707	327	443	770	72.5	48–96

[a] 8 a.m. for the Bluestem and Fife.

The detailed data taken on each of the 35 heads of wheat under observation are presented in Table 5, as are also totals for each va-

riety. The totals for the different varieties, grouped and summarized according to type, and a summary of all observations made on numbers of flowers blooming in the respective periods appear in Table 6.

Of the 247 flowers of the Dietz variety under observation, 111 bloomed at night, here considered as being between 5 p.m. and 7 a.m.; 59 bloomed in the forenoon, here considered as being between 7 a.m. and 12 m.; while 77 bloomed in the afternoon, here considered as being between 12 m. and 5 p.m., the total for the day being 136.

Of the 255 flowers of the Fultz variety, 42 bloomed in the forenoon and 74 in the afternoon, a total of 116 in the day as compared with 139 at night. This is one of the two varieties in which the night blooming was greater than the day blooming.

Of the 260 flowers of the Mealy variety, 65 bloomed in the forenoon and 90 in the afternoon, a total of 155 in the day as compared with 105 at night.

These three varieties just reviewed are of the soft red winter type. For this type the totals are 166 bloomings in the forenoon and 241 in the afternoon, a total of 407 in the day as compared with 355 at night.

The only representative of the soft white winter type of wheat is the Giant Squarehead, a bearded variety with the so-called square, clavate head. On the heads of this variety there were smaller numbers of flowers than in any other of the true winter wheats. Of the 150 flowers on the 5 heads 37 bloomed in the forenoon and 49 in the afternoon, a total of 86 in the day as compared with 64 at night.

The only representative of the hard red winter type of wheat is the Turkey. Of the 236 flowers here under observation 50 bloomed in the forenoon and 73 in the afternoon, a total of 123 as compared with 113 at night.

Bluestem and Fife belong to the hard red spring type of wheats, but were here grown as winter wheats. They bloomed somewhat later than the true winter wheats and in their period of blooming conditions for observation were not so good as in the earlier period. It seemed also that being grown out of their usual environment they furnished somewhat less favorable material for study. The data obtained agree with those on the winter types. On these the first morning observation was made at 8 a.m. instead of 7 a.m. Of the 147 flowers of the Bluestem variety observed 31 bloomed in the forenoon and 45 in the afternoon, a total of 76 in the day as compared with 71 at night. Of the 182 flowers of the Fife variety 43 bloomed in the forenoon and 35 in the afternoon, a total of 78 in the day, while

a larger number, 104, bloomed at night. This greater night blooming and the approximate equality of the day and night bloomings in the Bluestem variety is possibly due to the later hour of the first morning observation, although it agrees with the results obtained in the Fultz variety of winter wheat.

The totals for all winter varieties are, forenoon, 253; afternoon, 363; day, 616; night, 532; while for the spring varieties they are respectively 74, 80, 154, and 175.

In each variety except Fultz and Fife the total number of day-opening flowers is larger than the total number of those opening at night. The number of those opening in the afternoon is appreciably larger in each case, except Fife, than the number of those opening in the morning.

The data here recorded for the true winter wheats correspond more closely to those obtained for fall-sown wheat than to those obtained for spring-sown wheat at the Minnesota station. At the latter place the greater number of the common spring and durum wheat flowers opened at night, while the forenoon blooming was greater than the afternoon. The winter wheats at the latter place, however, bloomed more largely in the daytime, the larger number of flowers of the Kharkov variety blooming in the afternoon and of the Turkey in the forenoon. The Fultz variety at Arlington gives results inconsistent with the other winter varieties, although observations were made on it during the same period as on the other varieties. In Fultz a somewhat larger number of flowers opened at night than in the day, while the afternoon blooming as in the other varieties was greater than the forenoon. This difference is possibly due to causes associated with the variety, although for one head of the five the day blooming was larger and in another equal to the night blooming.

The whole series of observations seems to show that the time of blooming of wheat depends to some extent upon the variety. It can not be concluded, however, that this is the principal factor involved. There is also some evidence that the different environmental conditions of the two places of observation have influenced the time of blooming.

It is interesting to note in this connection that Salmon,[3] describing conditions in South Dakota, says: "It is exceptional to find wheat in bloom after 7 a.m. under normal conditions."

As these observations were made to determine the time of blooming of wheat flowers the causes of the differences observed were not

[3] Salmon, Cecil. Sterile florets in wheat and other cereals. *In* Jour. Amer. Soc. Agron., 6: 24–30. 1914.

determined. Temperature is possibly an important factor in determining the blooming time. Fruwirth[4] states that "When the temperature at 4:30 a.m. is above 14° C. the blooming begins at this hour." A lower temperature at this hour must then delay blooming. Low temperature was not a factor in delaying morning blooming at Arlington.

TABLE 7.—*Time of blooming of wheat flowers on 25 heads under observation from 4 p.m. May 26 to 10 a.m. May 30, 1914 at Arlington Farm, as indicated by number of flowers observed while in bloom, day and hour of blooming, and numbers blooming unobserved within stated periods.*

Flowers observed while in bloom.		Flowers not observed while in bloom	
Time.	Number.	Period in which blooming occurred.	Number.
May 26:			
4 p. m.	2		
May 27:			
7 a. m.	19	May 26, 5 p. m., to May 27, 7 a. m.	110
8 a. m.	33	May 27, 7 a. m. to 9 a. m.	2
10 a. m.	2	May 27, 9 a. m. to 10 a. m.	8
3 p. m.	23	May 27, 11 a. m. to 3 p. m.	96
4 p. m.	77		
5 p. m.	5		
May 28:			
6 a. m.	3		
7 a. m.	28	May 27, 5 p. m., to May 28, 7 a. m.	164
8 a. m.	62		
10 a. m.	6	May 28, 7 a. m. to 10 a. m.	2
11 a. m.	22	May 28, 9 a. m. to 11 a. m.	50
12 m.[a]	1		
7 p. m.	0	May 28, 12 m. to 7 p. m.	112
May 29:			
6 a. m.	1		
7 a. m.	2	May 28, 8 p. m., to May 29, 7 a. m.	180
8 a. m.	9		
9 a. m.	35		
11 a. m.	4		
12 m.	4		
3 p. m.	1	May 28, 12 m., to 3 p. m.	40
4 p. m.	4		
5 p. m.	3		
May 30:			
9 a. m.	1		
10 a. m.	3	May 28, 6 p. m., to May 30, 10 a. m.	34
Totals	350		798

[a] No observations made between 12 m. and 7 p.m. this day.

Blooming notes were taken at Arlington Farm on 1,477 wheat flowers. Of these, 454 were observed either in the actual process of

[4] Fruwirth, C. Die Zuchtung der landwirtschaftlichen Kulturpflanzen. Band 4, S. 107. Paul Parey, Berlin, 1910.

blooming or, owing to the frequent observations made, so soon after such blooming that the actual time could be recorded. In Tables 7 and 8 are recorded the numbers observed at the different hours of observation on the several days during which the flowers of these wheat heads were blooming, and also the numbers blooming within certain periods as determined by observations made at the beginning and end of these stated periods. These latter figures are set opposite the others so that the total number of bloomings may appear and thus indicate how dependable are the former records as indicating the actual blooming times of wheat flowers. In case of flowers observed while in bloom, bloomings taking place 30 minutes before or 30 minutes after an hour are included in the records as of that hour. In case of flowers not observed while in bloom the actual times recorded in each case marks the beginning and end of the period.

TABLE 8.—*Time of blooming of wheat flowers on 10 heads under observation from 2 p.m., June 1 to 3 p.m., June 5, 1914, at Arlington Farm, as indicated by numbers of flowers observed while in bloom, day and hour of blooming, and numbers blooming unobserved within stated periods.*

Flowers observed while in bloom.		Flowers not observed while in bloom.	
Time of observation.	Number.	Period in which blooming occurred.	Number.
June 1:			
2 p. m.	11		
3 p. m.	1		
June 2:			
8 a. m.	11	June 1, 5 p. m., to June 2, 8 a. m.	48
9 a. m.	22		
10 a. m.	14		
11 a. m.	2		
2 p. m.	1		
4 p. m.	2	June 2, 11 a. m. to 4 p. m.	28
June 3:			
8 a. m.	3	June 2, 5 p. m., to June 3, 8 a. m.	53
9 a. m.	1		
1 p. m.	3		
2 p. m.	4	June 3, 12 m. to 2 p. m.	16
3 p. m.	7		
4 p. m.	3		
June 4:			
8 a. m.	1	June 3, 5 p. m., to June 4, 8 a. m.	74
9 a. m.	2		
10 a. m.	3		
11 a. m.	1		
June 5:			
8 a. m.	1		
10 a. m.	3		
11 a. m.	3		
2 p. m.	4	June 5, 11 a. m. to 2 p. m.	6
3 p. m.	1		
Totals	104		225

The data in Tables 5 and 6 can not be derived directly from Tables 7 and 8 because of the slightly different methods employed in recording the time of blooming by hours and by periods.

In Table 7 are shown the detailed observations made on 25 heads between 4 p.m. May 26 and 10 a.m. May 30, the whole period of blooming of the flowers on these heads. The actual blooming time was recorded on 350 out of 1,148 of the flowers on these heads.

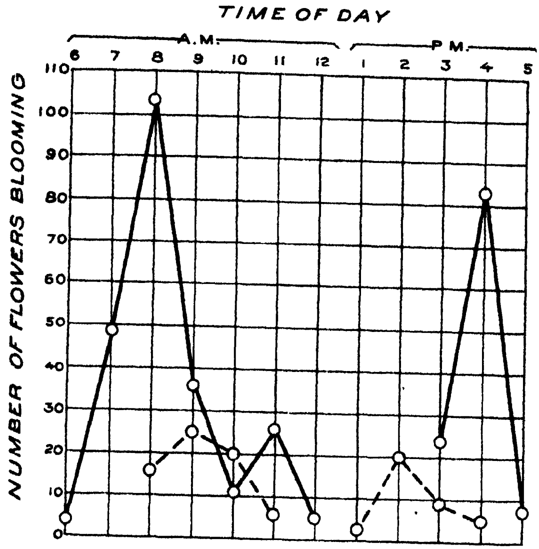

FIG. 11 Flowers observed in the actual process of blooming at the several hours of the day on 25 heads (solid line), and 10 heads (broken line) under observation at Arlington Farm.

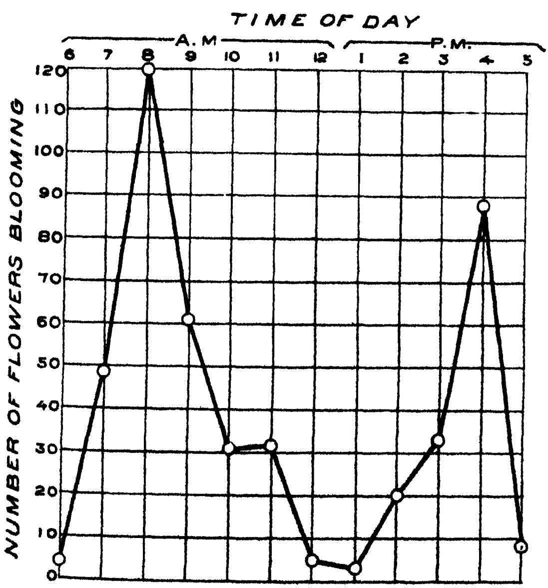

FIG. 12. Combination of line of figure 11.

In Table 8 are shown the detailed observations made on 10 heads of wheat between 2 p.m. June 1 to 3 p.m. June 5, 1914.

In Table 9 the numbers recorded as blooming on the several hours of observation in Tables 7 and 8 are combined and set down opposite the hour of blooming without regard to the day of blooming. These

data are then shown graphically in figures 11 and 12. In figure 11 the solid line represents the number of flowers observed in the actual process of blooming at the several hours of the day on the first lot of 25 heads under observation, while the broken line represents the same data for the second lot of 10 heads. The combined data for these two lots are shown graphically in figure 12.

TABLE 9.—*Number of flowers observed in the actual process of blooming at the different hours of the day on 25 wheat heads from 4 p.m., May 26, to 10 a.m., May 30, 1914; on 10 wheat heads from 2 p.m., June 1, to 3 p.m., June 5, 1914; and totals for these two periods.*

Time.	Flowers observed blooming.		
	On 25 heads.	On 10 heads.	Totals.
6 a.m.	4		4
7 a.m.	49		49
8 a.m.	104	16	120
9 a.m.	36	25	61
10 a.m.	11	20	31
11 a.m.	26	6	32
12 m.	5		5
1 p.m.		3	3
2 p.m.		20	20
3 p.m.	24	9	33
4 p.m.	83	5	88
5 p.m.	8		8
Totals	350	104	454

From these tables and figures it is evident that blooming was taking place at most hours of the day, but that the major part of it occurred at rather definite periods. The data indicate, when both the flowers observed to open and those not actually observed to open are considered, that there is (1) a morning period of extensive blooming, extending from about 7 to 9, (2) on at least some days a second forenoon period about 11 o'clock when the number of flowers blooming is less than during the first period, probably due to the period being shorter rather than to a decreased rate, and (3) a period about the middle of the afternoon, apparently most intense about 4 o'clock, beginning about 2 or 3 o'clock, according to conditions. This afternoon period is of about the same length as the early forenoon period and seems to be fully as intense, as many or more flowers blooming then as in the first period of the day. The number actually recorded as observed to open in this period is not so high because afternoon observations were not made on the second day. The number of

flowers blooming after this third period and before dark is probably not large, for on one day when observations were made at 7 p.m. no flowers were seen to open. This also agrees with general experience at Arlington, very few flowers being observed to open as twilight approaches.

It is not known whether or not there were periods of blooming in the darkness of night. It seems more probable that most if not all of this "night" blooming occurred both in Minnesota and at Arlington in the early morning about sunrise, which is between 4:30 and 5:00 o'clock at this time of year.

With regard to periods of blooming of wheat flowers Fruwirth states:[5]

> When the temperature at 4:30 a.m. is above 14° C. the blooming begins at this hour. Many flowers bloom then from this time to 5:30, while from this time until 9:00 the number is less. Very many bloom from 9–10 a.m., while very few bloom from 10 to 2:30 p.m. From 2:30 to 3:30 the number is again large, while from 3:30 to 7:00 p.m. it is again small. The principal blossoming time of the morning, which is made up of a preceding and succeeding blooming time, of which the first or the second may be the stronger, is followed in the afternoon by a later blooming time which approaches in amount to the weaker part of the morning blossoming time. (Translation by C. E. L.)

The periods of time during which the flowers under observation on each head were blooming is given in connection with the detailed blooming data. In the records of the Minnesota observations only the days on which blooming began and ended are given, these appearing in Table 1, 2, and 3.

The periods of blooming were longest for the winter wheats and Kubanka of the durums, all these averaging more than 6 days. Arnautka durum had the next longest period, 5 days. The common spring wheats had no head with a period of blooming of more than 4 days, and the average for all heads of the 3 varieties was about 3 days. The period of bloom of the heads of these three common spring varieties under observation began later than that for the other varieties, July 1, and was completed more rapidly. The longer period of blooming is possibly due to less favorable weather conditions in the earlier periods, for it is frequently observed that cool weather delays or prevents blooming.

The data showing the periods of blooming for the heads under observation at Arlington are given in detail for each head in Table 5, and the average for each variety is presented in Table 6, together with the range. In observations here recorded the periods of bloom-

[5] Loc. cit., S. 107, 108.

ing are expressed in hours, the data taken allowing such an approximation.

The periods for the different heads range from 48 to 96 hours. The average for all heads is 72.5 hours. The average duration for the different varieties ranges from 59.2 hours for Giant Squarehead, on which the number of flowers per head is low, to 82.6 hours for Fife. Turkey and Mealy average 69.2 and 69.8 hours respectively, while the average durations for Dietz, Fultz, and Bluestem are practically the same, being respectively 75.4, 75.6, and 75.8 hours.

The period of blooming of the flowers on a wheat head may vary from 2 to 7 days. The usual time when conditions are favorable is about 72 hours or 3 days.

SUMMARY.

At the Minnesota Agricultural Experiment Station and at Arlington Farm the time of blooming of 2,977 wheat flowers on 69 heads were recorded. Of these flowers 1,492 bloomed at night (from 5 or 6 p.m. to 7 or 8 a.m.), while 1,485 bloomed during the day. Of those blooming during the day 764 bloomed before noon and 721 bloomed after noon.

At Minnesota 70 more flowers bloomed at night than in the day, while at Arlington 63 more flowers bloomed in the day.

Some differences were observed in time of blooming that may be associated with varietal differences.

Two periods in the day of extensive blooming of wheat flowers were determined, the first a morning period from about 7 to 9, and the second a period about the middle of the afternoon. A secondary morning period about 11 occurs on at least some days. There are one or more periods at night or in the early morning, the exact time not being determined, but probably in the early morning.

The duration of blooming of the flowers on a wheat head may range from 2 to 7 days, the usual time being about three days.

The results of these observations should serve to correct the erroneous impression of many that wheat flowers always bloom very early in the morning (apparently true under some conditions) and that it is necessary to visit such plants at very early hours in order to secure opening anthers.

2. Natural Fertilization of Emasculated Wheat Flowers.

In this study flowers on a number of heads of several varieties of wheat were emasculated before their pollen was mature and left with-

out covering. Flowers on other heads of some of the same varieties were similarly emasculated and covered, at Minnesota with soft tissue paper held in place by light cord, at Arlington with paraffined (glassine) paper bags tied in place, these being considered as checks. The heads thus treated at both places were scattered at irregular intervals in rod rows, sown about 1 foot apart, so were always close to unemasculated heads.

TABLE 10.—*Flowers emasculated and seed set on heads of wheat not covered and covered after emasculation at the Minnesota Agricultural Experiment Station in 1914.*

(The first figure in each instance is number of flowers emasculated, while the second is the number setting seed.)

HEADS NOT COVERED.

Kharkov (A)	Kharkov (B).	Red Fife.	Haynes Bluestem.	"Velvet Chaff"	Glyndon Fife	Kubanka.	Arnautka.	Totals.
14, 7	16, 6	22, 11	16, 7	24, 21	28, 10	16, 12	16, 6	
20, 4	16, 7	28, 8	16, 8	28, 18	28, 12	16, 3	16, 6	
18, 8	16, 3	36, 11	16, 10	28, 10	16, 7	16, 3	16, 12	
18, 11	16, 6		16, 2	28, 12	16, 5	16, 6	16, 11	
18, 9	16, 1		16, 11	16, 12	16, 0	16, 7	16, 11	
16, 3	16, 6		16, 5	16, 6	16, 6	16, 8	16, 12	
18, 6	20, 10		16, 12	16, 6	16, 5	16, 3	16, 5	
	16, 3		16, 0	16, 7	16, 6	16, 2	16, 7	
	16, 4		16, 8	16, 3	16, 8	16, 3	16, 5	
	16, 7		16, 9	16, 11	16, 6	16, 5	16, 6	
Totals 122, 48	164, 53	86, 30	160, 72	204, 106	184, 65	160, 52	160, 81	1,240, 507
Percent 39.3	32.3	34.9	45.0	52.0	35.3	32.5	50.6	40.0

HEADS COVERED.

			16, 0	18, 0	16, 0			
			16, 0	16, 0	16, 0			
			16, 0	16, 0	16, 0			
			16, 0	18, 0	20, 0			
			16, 0	20, 0	16, 0			
			20, 0	16, 0	16, 1			
			20, 0	16, 1				
			16, 0					
			16, 0					
			16, 0					
Totals			168, 0	120, 1	100, 1			388, 2
Percent			0	1	1			0.5

For this work the varieties of wheat used at the Minnesota station were Kharkov (strains A and B), Red Fife, Haynes Bluestem, "Vel-

vet Chaff," Glyndon Fife, Kubanka, and Arnautka. The first two are strains of hard red winter wheat, the next four are common spring varieties, and the last two are varieties of durum. At Arlington Farm the varieties of wheat used for this work were: Fultz, Lancaster, C.I. 3614, Tennessee Fultz, C.I. 1733, C.I. 1933, China, Early Genesee Giant, Acme (Selection 2), and Kanred. The Early Genesee Giant is a soft white winter variety, the Kanred a hard red winter variety. All the other varieties named are of the soft red winter type.

The number of flowers emasculated and the number of seeds set on the different heads in the experiments at the Minnesota Agricultural Experiment Station are shown in Table 10. Kernels were formed by 507 of a total of 1,240 flowers on 70 heads emasculated and not covered. This is 40.97 percent of the flowers emasculated and not covered. When flowers were emasculated and heads covered only two kernels were produced by the 388 flowers worked, less than 1 percent. This shows that the error due to incomplete or untimely emasculation or the chance introduction of pollen within the wrappings is very small.

Where heads were emasculated, pollinated, and covered with tissue paper, 41.7 percent of the flowers worked formed seed. This shows that the tissue paper does not prevent the formation of seed when pollen is present.

In Table 11 are shown the numbers of flowers emasculated and the number of seeds set on the different heads employed in the experiments at Arlington Experiment Farm. Kernels were formed by 1,103 of a total of 1,324 flowers on 83 heads emasculated and not covered. This is 83.3 percent of the flowers emasculated and not covered. From 642 flowers on 40 heads emasculated and covered with paraffined paper bags 6 kernels only were formed. Three of these kernels were harvested from bags that had been torn, indicating that perhaps the pollen had entered through the holes in the bags.

The small number of kernels found on heads protected by these paper wrappings and bags indicates the effectiveness of these methods of protecting against foreign pollination. In the actual work of hybridization practically all of such errors would be avoided if the method of emasculating several days before pollinating the flowers is followed. At the time of pollination anthers not removed would probably be found, or evidence of fertilization might be discovered.

These results are in accord with those secured by Salmon working in South Dakota. He emasculated 199 wheat flowers before the

TABLE 11.—*Flowers emasculated and seed set on heads of wheat covered and not covered after emasculation at Arlington Farm.*

HEADS NOT COVERED.

Fultz.	Lancaster.	C. I. 3614.	Tennessee Fultz.	C. I. 1733.	C. I. 1933.	China.	Early Genesee Giant.	Acme (Sel. II).	Kanred.	Totals
16, 14	16, 13	16, 14	16, 15	16, 14	16, 14	16, 16	16, 15	16, 15	16, 12	
16, 14	16, 13	16, 14	16, 14	16, 16	16, 14	16, 11	16, 16	16, 14	16, 13	
16, 12	16, 15	16, 8	16, 15	16, 15	16, 14	16, 7	16, 15	16, 16	16, 13	
16, 15	16, 12	16, 12	16, 15	16, 16	16, 13	16, 10	16, 15	16, 14	16, 13	
16, 14	16, 12	16, 12	16, 15	14, 13	14, 10	16, 9	16, 14	16, 11	16, 10	
16, 13	16, 13	16, 15	16, 15	16, 16	16, 13	16, 13	16, 15	16, 15	16, 11	
16, 16	16, 11	16, 13	16, 14	16, 15	16, 14	16, 11	16, 15	16, 10	16, 13	
16, 15	16, 14		16, 16	16, 15	16, 13	16, 10	16, 11	16, 14	16, 14	
16, 12					16, 7[a]					
16, 15					16, 10[a]					
Totals 160, 140	128, 103	112, 88	128, 119	126, 120	158, 122	128, 87	128, 116	128, 109	128, 99	1,324, 1,103
Percent 87.5	80.5	78.6	93.0	95.2	77.2	68.0	90.6	85.2	77.3	83.3

HEADS COVERED WITH PAPER BAGS.

Fultz.	Lancaster.	C. I. 3614.	Tennessee Fultz.	C. I. 1733.	C. I. 1933.	China.	Early Genesee Giant.	Acme (Sel. II).	Kanred.	Totals
16, 0	16, 0	16, 0	16, 0		16, 0	16, 0				
16, 0	16, 0	16, 0	16, 0		16, 0	16, 0				
16, 0	16, 0	16, 0	16, 0		16, 0	16, 0				
16, 1	16, 1[b]	16, 0	16, 0			16, 0				
20, 0	16, 0	16, 0				16, 0				
16, 0	16, 0	16, 2[b]				16, 0				
14, 2	16, 0	16, 0				16, 0				
16, 0	16, 0	16, 0				16, 0				
16, 0										
Totals 144, 3	128, 1	128, 2	64, 0		48, 0	128, 0				642, 6
Percent 2.	.7	1.6	0		0	0				1.

[a] Upper spikelets left on these heads and not emasculated.

[b] Bag torn.

pollen was ripe and left them exposed in the field without cover. Of these, 152, or 76.3 percent, produced grain. A single head similarly emasculated, but covered with a bag, produced no grain.

When wheat flowers are emasculated and not pollinated the glumes, apparently some time after the regular time of blooming, open and remain open for several days. The style also grows to an abnormal length. Opportunity is thus presented for the entrance of pollen. When fertilization has taken place the glumes remain closed. It is very unusual for one to succeed in securing the fertilization of all of the flowers pollinated by hand. Those not fertilized, amounting often to 50 percent or more of those pollinated, would remain open and at least some of them would be likely to receive foreign pollen and be fertilized.

In view of the results obtained in these experiments there seems no doubt that in studies of inheritance in wheat hybrids and in breeding operations where hybrids of known parentage are desired, it is necessary to protect emasculated flowers from undesired pollination.

That this practive of covering emasculated flowers has sometimes not been considered necessary, is evident from the following statement made by Carleton:[6]

> After trying the experiment for some time, the practice of tying paper or cloth bags over the cross-pollinated heads has been abandoned. Often the head is much injured by the operation, particularly in times of wet weather, and there does not seem to be much need of it. After some experience one can determine very readily whether there has been any natural cross-pollination other than the one intended simply from the nature of the results, and really such an instance seems never to have occurred in our experience.

Others engaged in wheat breeding have also considered it unnecessary to cover the flowers when crossing is being done. It is shown by results here reported that this practice is likely to result in undesired pollinations. Where accurate records of parentage are at all essential emasculated flowers should doubtless be protected.

SUMMARY AND CONCLUSION.

At the Minnesota Agricultural Experiment Station kernels were formed by 507 of 1,240 wheat flowers emasculated and left unprotected, while at Arlington Farm 1,103 kernels were formed when 1,324 flowers were similarly treated. Less than 1 percent of flowers protected after emasculation by paper bags or wrappings produced kernels. It is necessary to protect emasculated flowers in order to prevent undesired pollination.

[6] Bailey, L. H. Plant Breeding, p. 294. The Macmillan Co., New York, 1908.

THE VARIETIES OF SMALL GRAINS AND THE MARKET CLASSES OF WHEAT IN UTAH.[1]

GEORGE STEWART.

In the summer of 1918 an attempt was made to learn which varieties of small grains were being grown by the farmers of Utah. This study consisted of two parts (1) a field survey in which wheat, oat, and barley fields were visited and the variety determined, and (2) the collection of samples of these grains from all available local sources. These samples were grown on the college farm at Logan, Utah, together with 91 lots of oats grown by the writer at Cornell University in 1917, the identification of which Montgomery[2] reported last year. These oats and 34 samples collected in Utah and southern Idaho were planted for the purpose of classification and also to assist in a study of Etheridge's key. As the classification work is not completed, it is not now reported.

The survey, though incomplete, was carried far enough to give some interesting data. Oats were classified according to Etheridge's key,[3] barley according to Harlan's key,[4] and wheat, so far as possible, in accordance with the yet unpublished classification of Ball and Clark. Lack of even a tentative key made it impossible to be sure of all the varieties of wheat. A variety locally called Touse caused particular trouble, as this name occurs in Utah attached to Bluestem, Defiance, New Zealand, and to another variety the true name of which has not up to date been ascertained.

Table 1 shows the results of the survey by counties. It should be mentioned that the field survey was made too late to obtain samples from the dry-farm fields in some sections. Two-thirds of the dry-farm wheat in Utah is Turkey. The tables do not therefore show as high a percentage of Turkey as is actually grown.

[1] Contribution from the Department of Agronomy, Utah Agricultural Experiment Station, Logan, Utah. Read at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 7, 1919, by Dr. F. S. Harris.

[2] Montgomery, E. G. The identification of varieties of oats in New York. *In* Jour. Amer. Soc. Agron., 10, no. 4, p. 171–174. 1918.

[3] Etheridge, W. C. A classification of the varieties of cultivated oats. N. Y. (Cornell Univ.) Agr. Expt. Sta. Memoir 10, p. 79–172, fig. 12–33, pl. 1–22. 1916.

[4] Harlan, Harry V. The identification of varieties of barley. U. S. Dept. Agr. Bul. 622, 32 p., pl. 1–4. 1918.

TABLE I.—*Varieties of wheat, oats, and barley grown in Utah and the market class of each variety (data by counties in number of fields of each variety visited in 1918).*

Variety.	Market class	County.										Total.
		Box Elder.	Davis.	Salt Lake.	Tooele.	Utah.	Juab	Wayne	Sevier.	San Pete.	Cache.	
	WHEAT.											
Dicklow	Common white		16	31		111	7	4	25	42	37	263
New Zealand	do			29		25		2	34	29	30	149
Marquis	Hard red spring		4	6	8	10	15	1	1	3	41	89
Kubanka	Durum						2	3	68			73
Bluestem	Common white	22	12		6	1					31	72
Turkey	Hard red winter		4	2	13	4	13			2	18	56
Gold Coin	Common white		3								41	44
Kofod	do					9	34					43
Defiance	do	1	2	4					7	5	3	22
Little Club	White club	1	4	2		1					10	18
Sonora	do	2		3			4	2			3	14
Fife (Jones' Winter)	Soft red winter		2								5	7
Genesee Giant	White club		5									5
Lofthouse	Common white	3									2	5
Odessa	Soft red winter		1								3	4
Droubay	Common white				4							4
Polish	Durum											2
Ghirka	Hard red winter								2			2
Touse	Common white						7	6	3	2		18
Mixed	Mixed				16							16
Total		29	53	77	47	161	82	18	140	83	226	906
	OATS.											
Swedish Select	Western white	16	4	23	7	21	15	7	34	22	29	178
Lincoln	do			4	3	6	7		2	2	3	27
Silvermine	do						3			2	3	8
Kherson	Yellow				4			2				6
Storm King	Western white					2		2			1	5
Belyak	do								4			4
White Tartar	White	1		1		2						4
Monarch selection	Black									3		3
C. I. No. 620	White				2		1					3
Boswell Winter	Black						2					2
Green Mountain	White					2						2
Black Tartarian	Black					1						1
June	Western white						1					1
Sparrowbill	do			1								1
Wild	Wild						1		1	2		4
Mixed	Mixed				6							6
Total		17	4	29	22	34	30	11	41	31	36	255
	BARLEY.											
Coast		7	6	4	3	9	4		4		12	49
Manchuria							2		2	1	4	9
Nepal (Pearl)								6		1	2	9
Utah Winter			1			5						6
Two-row									2	3		5
Total		7	7	4	3	14	6	6	8	5	18	78

TABLE 2.—*Percentages of leading varieties of small grains in Utah in 1918 (data from Table 1).*

Wheat. Variety.	Percent.	Oats Variety.	Percent.	Barley. Variety.	Percent
Dicklow	29.0	Swedish Select	69.7	Coast	62.6
New Zealand	16.4	Lincoln	10.6	Manchuria	11.6
Marquis	9.8	Silvermine	3.1	Nepal	11.6
Kubanka	8.1	Kherson	2.4	Club	7.8
Bluestem	7.9	Storm King	2.0	Two-row	6.4
Turkey	6.2	Belyak	1.6		
Gold Coin	4.8	Nine others	8.2		
Kofod	4.7	Mixed	2.4		
Defiance	2.4				
Little Club	2.0				
Touse	2.0				
Sonora	1.8				
Eight others	3.1				
Mixed	1.8				
Total	100.0		100.0		100.0

The varieties of wheat common on irrigated farms were Dicklow, New Zealand, Marquis, Bluestem, Defiance, and Touse; on dry farms, Turkey, Marquis, Kofod, Gold Coin, Bluestem, and Sonora. Other varieties are not widely known.

It is interesting to note that Kubanka, one of the spring durums, altho originally introduced into the United States for the regions of most severe drouth, was found entirely under irrigation on low water-logged lands. Farmers reported that other varieties lodged and rusted, whereas this variety lodged but did not rust. Farmers liked Kubanka on this account, but they have trouble in selling it, as millers do not care to handle it because of difficulty in milling.

Another interesting point is that out of 89 fields of Marquis, 54 were grown under irrigation. This wheat was brought into Utah for a spring grain on the dry farms. It was also peculiar that in most cases irrigated Marquis was hard and vitreous, whereas nearly all irrigated Turkey wheat was filled with yellowberry to the extent of 75 percent or more.

Marquis and Dicklow were accused of shattering. Many of the farmers of Utah run cattle on the National forest ranges in summer and winter them on straw. These men dislike Turkey and Kubanka on account of beards in the straw, which stick in the mouths of the cattle and are therefore objectionable.

It may be of interest to note the jumble of varietal names. In Davis County Dicklow was known as Dicklow, Australian Club, California Club, and Club; in Salt Lake County as Excelsior, California

Club, and Club; in Utah County as Dicklow and California Club; and in Sevier County as Club, California Club, Dicklow Club, and Dicklow. New Zealand was generally known by its true name, but was found in Cache County being grown as Bluestem; in Salt Lake County as Ninety-Day; in Wayne and Juab counties as Touse; and in Sanpete as Ruby. Bluestem was usually called Bluestem, but was found in Cache County called New Zealand; in Boxelder and Utah, Ninety-Day; in Tooele, Touse and Sonora. Sonora was usually called Red Chaff. It occurred as Red Chaff and Sonora in Salt Lake County, as Red Fife in Juab, and as Red Russian in Boxelder.

Kofod has been written "Koffoid" in publications of the Utah station and of the United States Department of Agriculture. Relatives of the man for whom the grain was named were found and it was learned that he and all his people write their name Kofod. Accordingly this spelling has been adopted by the Utah station and the word is so written herein.

Field agriculturists in Utah have long urged the farmers to standardize their varieties, but so long as no grading was done in the State this advice was unheeded. In August, 1917, a Federal grain supervision office was established in Salt Lake City. Grading was then begun by the Utah-Idaho Grain Exchange. Results for the first year have just been completed. In the year ending July 31, 1918, the Utah-Idaho Grain Exchange graded 1,747 cars. Table 3 shows the percentage of the total in each class and the percentage of grades in each class influenced by "wheat of other classes" and by "heat damage."

TABLE 3.—*Percentage of wheat in each class and percentage of grades in each class determined by wheat of other classes and by heat damage.*

Class.	Common variety in each class.	Percentage of total in this class	Percentage of class graded down because of—	
			Wheat of other classes.	Heat damage.
Hard red spring	Marquis	10.3	21.6	4.7
Durum	Kubanka	...	...	..
Hard red winter	Turkey	25.1	11.7	22.6
Common white	New Zealand, California Club, Dicklow, Bluestem, Touse	19.8	44.7	.9
White club	Little Club	.8	46.7	...
"Mixed"	......	44.0	...	19.5
Average		...	15.3	13.2

Table 3 shows that 44 percent of the 1,747 cars was graded mixed wheat on account of wheat of other classes. Wheat is not classified

TABLE 4.—*Percentage of common white wheat and its subclasses in each grade and percentage of each determined by wheat of other classes.*

Grade.	Common white.		Hard white.		Soft white.	
	Percentage of class in grade.	Percentage of grade determined by wheat of other classes.	Percentage of subclass in grade.	Percentage of grade determined by wheat of other classes.	Percentage of subclass in grade.	Percentage of grade determined by wheat of other classes
1	13.9		14.3		13.8	
2	56.0	40.8	53.3	35.5	56.8	42.3
3	24.3	60.0	27.2	87.5	23.4	57.4
4	3.2	50.0	5.2	50.0	2.6	50.0
5	2.3				3.0	
Sample	.3				.4	
Average		44.7		50.0		43.7

as mixed unless there is an admixture of other classes in excess of 10 percent. No matter how many varieties there may be that fall into the same class or subclass, a mixture of these affects neither the class nor the grade. Let us take the class common white as an example. The survey showed that there are in Utah nine varieties that grade common white, four of which are common. Of these nine, seven (Dicklow, Bluestem, Kofod, Gold Coin, Lofthouse, Droubay, and Touse) are soft white, and two (New Zealand and Defiance) are hard white. Bluestem, New Zealand, Defiance, Dicklow, and Touse occurred as a mixture in the same field many times. The admixture of two or even all of these varieties would have caused neither the classification of the wheat as "mixed" nor the placing of it in a lower grade. Though such mixtures would not disturb the grading, they would markedly influence the yield, because New Zealand and Dicklow are far better yielders under irrigation than are Touse or Bluestem. Defiance also has been a good yielder. In three counties the writer made inquiries of fifty farmers concerning their choice of the first, second, and third best irrigated wheats. The results are shown in Table 5.

TABLE 5.—*Varieties of wheat preferred by 50 farmers on irrigated farms in three counties.*

Variety.	Choice.			Total.
	First.	Second.	Third.	
Dicklow	26	20	4	50
New Zealand	18	21	11	50
Defiance	1	3	6	10
Bluestem	1	3	18	22
Marquis	2	2	7	11
Touse	2	1	4	7
Total	50	50	50	150

Table 5 shows that although many of the farmers consulted were not attempting to grow them, they were satisfied in their own minds as to which varieties of wheat were best. Without actual data it is impossible of course to say which variety would be the highest yielder, but judging from fields seen the writer would chose Dicklow, New Zealand, and Defiance as the three best varieties for irrigation. Dicklow has not been tested by the Utah station, but New Zealand and Defiance have been the highest yielders of the varieties grown.

Table 6 shows the approximate number of bushels graded down, in part because of the influence of wheat of other classes and heat damage. In all, the grade of 512,320 bushels was influenced. If the 768,000 bushels that were classified as "mixed" wheat are added to this figure the total affected is 1,280,320 bushels, or 73.3 percent of all wheat marketed. These figures assume that each car carried just 1,000 bushels, the minimum set by the Food Administration. These are conservative figures, as some held more than the minimum.

TABLE 6.—*Approximate total number of bushels in each class and the approximate number of bushels graded down in the Utah-Idaho Grain Exchange in 1918 because of wheat of other classes and heat damage.*

Class.	Number of cars.	Approximate number of bushels in class.	Approximate number of bushels graded down because of		Total number of bushels
			Wheat of other classes.	Heat damage.	
Hard red spring	180	180,000	38,880	8,460	47,340
Hard red winter	437	437,000	51,130	98,760	149,890
Common white	348	348,000	155,560	3,130	158,690
White club	14	14,000	6,540	....	6,540
Mixed	768	768,000	....	149,860	149,860
Total	1,747	1,747,000	252,110	260,210	512,320

TABLE 7.—*Approximate monetary loss due to influence of wheat of other classes and heat damage.*

Class.	Loss due to wheat of other classes.	Loss due to heat damage.	Total loss.
Hard red spring.....	$ 388.80	$ 84.60	$ 473.40
Hard red winter.....	511.30	987.60	1,498.90
Common white........	1,555.60	31.30	1,586.90
White club...........	65.40	....	65.40
Mixed..............	....	1,498.60	1,498.60
	$2,521.10	$2,602.10	$5,123.20
Loss due to classification as mixed..........................			$8,991.60
Total..			$13,114.80

Table 7 shows the approximate monetary loss to wheat growers due to wheat of other classes and heat damage. In making this table, it was assumed that the grades reduced were cut only one grade, and that only half of this reduction was due to these two factors. This places the loss at 1 cent a bushel for each grade affected. The loss was probably considerably greater than this, because some wheat was cut more than one grade. Some of the cutting was also influenced more than half by these two factors, for the total damage other than heat was only 20.2 percent and the percentages of grades influenced by moisture, by inseparable foreign matter, and by odor were 1.8 percent, 2.8 percent, and 0.8 percent, respectively, making a total for all wheat of 25.6 percent for these factors as opposed to 28.5 for wheat of other classes and heat damage. It is probable that a part of the reduction in grade due to test weight, 33.5 percent, was also due to light mixtures of grain or weed stems.

The Yearbook of the United States Department of Agriculture for 1917 gives the total production of wheat in Utah as 5,650,000 bushels. A considerable part of the 1,747 cars were from southern Idaho; therefore, the 1,747,000 bushels graded by the Utah-Idaho Grain Exchange does not represent more than 25 percent of the crop, possibly much less. In order to arrive at anything like an accurate estimate of the growers' losses, it is necessary to multiply the figures in Table 7 by at least 4. This would place the losses to farmers of Utah and southern Idaho at $10,084.40 for grading down due to wheat of other classes; at $10,408.40 for grading down due to heat damage; and at $35,966.40 due to the classification of 44 percent of the crop as mixed wheat. The total loss then is at least $52,458.20 due to the admixture of unlike varieties and to weed injury. In addition there was an average for all classes of 1.58 percent dockage. Some one has to pay freight on this useless material from the farm to the warehouse at which it is screened out and also the cost of handling on the farm. Irrigated farmers had a still greater loss, the dockage being 2.02 percent on common white, the wheat mostly grown under irrigation.

SUMMARY.

1. Varieties of small grain grown in Utah are badly mixed.
2. Varietal names are frequently misapplied.
3. The most common varieties of wheat and the ones that seem best adapted are Dicklow and New Zealand on irrigated farms, and Turkey, Kofod, Bluestem, and Gold Coin on the dry farms. Oats are almost standardized to the Swedish Select variety.
4. Market grades substantiated the results of the field survey.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership as reported in the March Journal was 515. Since that time 11 new members have been added, 3 have been reinstated, and 4 have resigned, a net gain of 10 and a present membership of 525. The names and addresses of the new and reinstated members, the names of those who have resigned, and such changes of address as have come to the notice of the secretary or the editor, follow:

New Members.

Brockson, W. I., Agr. Serv. Bur., Amer. Agr. Chem. Co., Boston, Mass.
Bruce, Wm. F., New Vienna, Ohio.
Cowart, I. E., Substation No. 1, Beeville, Texas.
Duncan, J. R., East Lansing, Mich.
Hastings, Wm. R., 16 West Mitchell St., Atlanta, Ga.
Langebacher, R. A., Farm Crops Dept., Columbia, Mo.
Megee, C. R., East Lansing, Mich.
Musgrave, G. W., Agr. Expt. Sta., New Brunswick, N. J.
Nicolson, J. W., East Lansing, Mich.
Putnam, G. W., Chatham, Mich.
Wilson, A. L., County Agr. Agent, Morgan, Utah.

Members Reinstated.

Cox, J. F., East Lansing, Mich.
Raymond, L. C., Macdonald College, Quebec, Canada.
Richey, F. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.

Members Resigned.

French, W. L., Wright, A. H., Youngblood, Bonney, Lowry, M. W.

Changes of Address.

Chapman, James E., Div. of Soils, University Farm, St. Paul, Minn.
Dustman, Robert B., Dept. of Soils, Ohio State Univ., Columbus, Ohio.
Gustafson, A. F., Soil Technology, Cornell Univ., Ithaca, N. Y.
Hopt, Erwin, Cambridge, Nebr.
Johnson, Geo. F., 67 W. Tenth Ave., Columbus, Ohio.
Laude, H. H., Agr. Expt. Sta., College Station, Texas.
Milton, R. H., 117 Cheapside, Lexington, Ky.
Murray, James, Nobleford, Alberta, Canada.
Rueda, Buenaventura, Quinta de los Molinos, Habana, Cuba.
Smith, Raymond S., Room 653 Agr. Bldg., Univ. of Ill., Urbana, Ill.
Stadler, L. J., Farm Crops Dept., Univ. of Mo., Columbia, Mo.
Thysell, John C., Northern Great Plains Field Sta., Mandan, N. Dak.
Tinsley, J. D., Box 673, Albuquerque, N. Mex.

NOTES AND NEWS.

R K. Bonnett, formerly assistant professor of farm crops at the Kansas State Agricultural College, has been professor and head of the department of farm crops in the Idaho college and station since September 1.

W. I. Brockson, formerly with the Iowa and Illinois stations, is now with the service bureau of the American Agricultural Chemical Company, with headquarters at Boston.

W. P. Brooks, agriculturist of the Hatch (Mass.) station during its entire existence and director of the Massachusetts stations since 1906, has resigned to become consulting agriculturist of these stations. F. W. Morse has been appointed acting director.

M. O. Bugby has resigned as superintendent of experiment farms in Trumbull and Mahoning counties, Ohio, and has been succeeded by J. P. Markley, formerly superintendent of the test farm at Strongsville, to which position W. H. Reutenik has been appointed.

Kenyon L. Butterfield, president of the Massachusetts Agricultural College, is in Europe as a member of the army overseas educational commission. Several college and station men are associated with him in this work, including Director E. A. Burnett of the Nebraska station, Director Harry Hayward of the Delaware station, and Professor L. E. Call, agronomist of the Kansas station.

J. P. du Buisson, a member of this society and formerly a graduate student at Cornell University, died of sunstroke in Senekal, South Africa, July 27, 1918. Since his return to South Africa Mr. du Buisson had been engaged in teaching soil chemistry in the University of Potchefstroom, South Africa.

W. F. Gericke of the California station is on leave of absence for graduate study.

A. E. Grantham, agronomist of the Delaware station, is acting director of that station during the absence of Director Hayward in Europe.

C. H. Helm of the department of farm crops, University of Missouri, has returned to his duties after six months' service in the National Army.

E. A. Hodson of Cornell University has been appointed assistant professor of agronomy in the Delaware college.

R. R. Hudelson has resumed his work as assistant professor of soils in the Missouri college of agriculture, after a year and a half in military service.

E. M. McDonald, assistant professor of farm crops in the University of Missouri, has returned to his duties after twenty-one months of army service.

George D. Musgrave has been appointed assistant professor of agronomy in the New Jersey college of agriculture.

H. S. Records is home project worker with the rank of assistant professor in the Northwest School of Agriculture, Crookston, Minn.

The Agricultural History Society was organized at Washington, D. C., February 14, 1919, to "stimulate interest, promote study, and facilitate publication of researches in agricultural history." The officers are Dr. Rodney H. True, Bureau of Plant Industry, Washington, D. C., president; Prof. Wm. J. Trimble, Agricultural College, N. Dak., vice-president; and Lyman Carrier, Bureau of Plant Industry, Washington, D. C., secretary-treasurer. Prof. R. W. Kelsey, Haverford, Pa., and O. C. Stine, Office of Farm Management, Washington, D. C., are additional members of the executive committee. Any one interested in the subject is eligible to membership and is invited to send his application, with annual dues of $1.00, to the secretary-treasurer.

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A STUDY OF THE RELATION OF SOME MORPHOLOGICAL CHARACTERS TO LODGING IN CEREALS.[1]

R. J. GARBER AND P. J. OLSON.

INTRODUCTION.

One of the perplexing problems which confronts the cereal plant breeder is the production of nonlodging small grains which at the same time possess high yielding capacity. In 1916, a project was organized at the Minnesota Agricultural Experiment Station with the object of determining whether some simple morphological character is closely correlated with lodging or nonlodging.[2] With such a criterion the matter of studying lodging would be much facilitated, since the nonlodging forms could be immediately isolated without waiting three or more years to determine the promising selections or parental stock. A few investigations bearing on this subject have been made.

REVIEW OF LITERATURE

Moldenhawer,[3] working with wheat and barley, found number of vascular bundles to be a distinguishing characteristic for different sorts and that nonlodging sorts could be selected by means of the

[1] Published with the approval of the Director as Paper No. 171 of the Journal series of the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn. Received for publication April 8, 1919.

[2] The writers are indebted to H. K. Hayes, head of the section of plant breeding, Division of Agronomy and Farm Management, for assistance in outlining and carry out this project.

[3] Moldenhawer, K. Die Gesfäszbundelzahl und ihre Bedeutung für die Lagerung des Getreides. *In* Zeitsch. Landw. Versuchs. Österr., 17: 886–891. 1914.

number of vascular bundles. In general, the more nonlodging forms contained the greater number of bundles.

Albrecht[4] accepted without question the breaking strength of straw as an index to lodging. His conclusions are based on individual plants of a single variety of winter wheat, grown at Köngsberg, Germany, in 1905. Evidence is presented showing (1) a fairly high correlation between breaking strength and the weight of 1 cm. of straw, (2) some correlation, fairly consistent, between breaking strength and total area of a cross section of the vascular bundles, (3) some correlation between breaking strength and thickness of culms, and (4) little correlation between breaking strength and thickness of sclerenchyma.

MATERIAL AND METHODS.

Selections of varieties and crosses which appeared to be homozygous for botanical characters were used. Within the various small grains the most lodging and most nonlodging forms were selected. In all, 15 strains of barley, 7 of oats, 2 of spring wheat, 2 of winter wheat, and 1 of winter rye were studied.

Most of the material was grown both under field and greenhouse conditions. A separate study was made of the morphological characters of each sort grown under the two environments. Data on lodging, yield, and height represent an average of three years' results, except where otherwise stated.

The rod-row plots in the plant-breeding nursery furnished the source of the notes on these characters. Each sort was grown on two or three systematically distributed plots each of which consisted of three or four rod rows. The rank of the various strains as to lodging was determined by two notes, one on the percentage of the plot lodged and the other on the average degree lodged, *i. e.*, the average degree of the angle which the lodged grain made with the normal condition. For instance, if half of the plot under consideration was down flat it would be noted as follows,—percentage lodged 50, degree lodged 90.

The material for study[5] was collected and fixed after internodal growth had ceased, but before the grain was entirely ripe. Sections

[4] Albrecht, K. Untersuchungen über Korrelationen im Aufbau des Weizenhalmes, welche für die Lagerfestigkeit des Getreides von Bedeutung sind. *In* Landw. Jahrb., 37: 617–672. 1908.

[5] The authors wish to express their appreciation of the aid and helpful suggestions of Dr. C. O. Rosendahl, of the Botany Division of the University of Minnesota, in regard to histological methods and for the kindly interest shown in analyzing the data.

of the culm about a centimeter in length were taken at the places indicated (first internode considered that bearing the panicle or spike) by means of a razor. After the culm fragments were desilicified and embedded in celloidon, sections of from 20 to 30 microns in thickness were made. The sections were stained with safranin and Delafield's haematoxylin and afterward mounted. Safranin stained the lignified tissue a bright red while the phloem was stained blue by Delafield's haematoxylin.

Briefly, the morphological data taken were as follows: diameter of culm with a caliper before embedding, number of vascular bundles, thickness of culm,, thickness of sclerenchyma, and average diameter of vascular bundles including their surrounding lignified cells. All microscopical measurements except those under oil immersion were made by means of a millimeter eye-piece and then reduced to a fraction of a millimeter. Thickness of culm wall was obtained by measuring the average distance from the periphery of a cross section to its inner boundary. The heavy-walled, deep-stained cells which make up the sclerenchyma tissue found near the periphery were measured at several places to obtain their average width or thickness. The average diameter of vascular bundles, including their surrounding lignified cells, was obtained by measuring the longest and shortest diameter of each of from seven to ten bundles of each individual and then computing the average diameter from the measurements thus obtained. The number of vascular bundles was ascertained by simply counting those which appeared in a cross section of the culm (see Plate 6, figure 1).

The foregoing paragraph is a somewhat brief description of the treatment accorded each mounted cross section. Each cross section represented one plant and each pure-line strain was represented by from 8 to 25 cross sections.

A maceration study was made of the material grown in the greenhouse to determine the average length of the lignified cells. Schultze's maceration method was employed. A composite sample of from 15 to 25 individuals of each strain was macerated and mounted in duplicate and then stained with safranin. Twenty-five deeply stained cells on each slide were measured for length, thus making fifty measurements for each strain. A study was made of a composite sample representing the strain rather than considering separately each individual of a strain, as it was found in preliminary work that individuals of the same pure line did not differ significantly for the character under consideration.

TABLE 1.—*Data on percentage of lodging, degree of lodging, yield, and height of plant of various strains of barley, oats, and wheat.*

Nursery selection No.	Variety.	Type.	Percentage of lodging.				Degree of lodging.				Rank.	Average yield, bushels.	Average height, inches.
			1916	1917	1918	Ave.	1916	1917	1918	Ave.			
Barley:													
II–16–116	Manchuria × Svanhals . . .	2-row	0	3	0	1	0	47	0	16	1	39.2	39
II–16–77	S. African × Manchuria . . .	6-row	0	41	25	22	0	70	33	34	2	53.1	31
I–16–15	Servian . .	do	8	46	78	44	20	31	27	26	3	44.3	32
II–16–78	Bohemian × Manchuria . .	2-row	0	50	100	50	0	80	13	31	4	41.5	37
I–16–60	Chicago No. 63 . .	6-row	0	67	100	56	0	70	20	30	5	40.6	35
I–16–33	Lake City . . .	do	52	25	100	59	45	40	10	32	6	44.1	37
I–16–14	Trebi	do	5	59	100	55	15	72	68	52	7	49.1	30
I–16–13	Lion	do	3	62	92	52	13	69	88	57	8	54.3	30
I–16–44	Manchuria Excelsior	6-row	57	80	67	68	62	85	18	55	9	47.3	38
I–16–8	Featherston . .	do	75	87	92	85	50	76	17	48	10	40.2	37
I–16–3	Sandrel	do	67	95	93	85	42	85	33	53	11	50.0	30
I–16–45	Scotch 20816.	do	66	92	95	84	72	89	37	66	12	42.6	35
II–16–131	Svanhals × 2r/6r.	2-row	82	63	100	82	73	83	53	70	13	41.7	39
I–16–2	Featherston . .	6-row	88	99	100	96	58	85	50	64	14	38.9	31
I–16–31	Highland Chief .	do	90	97	100	96	62	90	88	80	15	55.2	37
Oats:													
I–15–40	Gartons . .	Side	95	0	42	46	93	0	35	43	1	70.1	43
I–06–28	Dept No. 5168	Open	100	13	72	62	100	10	28	46	2	68.6	38
I–15–99	Swedish Select	do	100	33	80	71	100	32	90	74	3	77.2	48
I–17–72	Sixty-Day . . .	do			43	43			30	30	1	81.3[a]	34[a]
I–17–40	S. P. I. No. 33644.	do			48	48			60	60	2	71.1[a]	34[a]
I–17–70	Sixty-Day	do			100	100			57	57	3	74.9[a]	34[a]
Wheat:													
I–01–3	Odessa	Winter	0	37		19	0	8		4	1	32.9[a]	45[a]
I–03–68	Turkey (Cosgrove)	do	90	100		95	54	62		58	2	28.6[a]	37[a]
II–06–39	Preston . . .	Spring	6	0	67	24	15	0	20	12	1	27.4	42
Check	Bluestem	do	24	10	67	34	45	13	23	27	2	24.8	43

[a] One year only.

RELATION OF YIELD AND HEIGHT OF PLANT TO LODGING.

The data from which the rank of the various sorts as to lodging was determined are listed in Table 1. Here also may be found the average yield and height of the sorts studied except winter rye, for which no data were available. Under Minnesota conditions the winter rye used is one of the most nonlodging cereals.

It is apparent from the table that there is no correlation either between yield and lodging or between height of plant and lodging. Barley strain II–16–77 with an average yield of 53.1 bushels stands up well, while strain I–16–31 with an average yield of 55.2 bushels lodges badly. Similarly comparing heights gives no clew to their

stiffness of straw. For example, consider the two barley sorts II–16–77 and I–16–2. Both have an average height of 31 inches, but one has stiff straws, while the other has not. Other examples easily could be pointed out from the table. It would seem that other things being equal the taller, heavier yielding strains, would be more likely to fall. Evidently there are other factors of more importance in determining the sorts most susceptible to lodging.

It may be of interest to note that *Hordeum vulgare* or *Hordeum distichum* are not associated exclusively with either lodging or non-lodging forms. In each of these two classes both 2-rowed and 6-rowed barleys are found.

CULM MEASUREMENTS AND NUMBER OF VASCULAR BUNDLES.

Tables 2 and 3 present the assembled average results of the culm measurements, average number of vascular bundles, number of individuals representing each sort, and the rank of the various strains as to nonlodging.

TABLE 2.—*Average data on culm measurements of barley.*

Rank as non-lodgers.	Nursery selection number.	Field material measured at 4th internode: Number of individuals.	Diameter of culms.	Thickness of culm walls.	Number of bundles.	Total area of bundles.	Area of scleren-chyma.	Greenhouse material measured at 5th internode: Number of individuals.	Diameter of culms.	Thickness of culm walls.	Number of bundles.	Total area of bundles.	Area of scleren-chyma.
			mm.	*mm.*		*sq.mm.*	*sq mm*		*mm.*	*mm*		*sq.mm.*	*sq mm.*
1	II–16–116[a]	13	4.023	0.437	34.15	0.386	0 857						
2	II–16–77	12	3.875	.473	33.09	.426	.708	25	3.524	0.597	35.28	0.461	0.545
3	I–16–15	15	4.407	.448	35.47	.428	.752	22	4 273	.754	49.78	.591	.820
4	II–16–78[a]	15	4.207	.389	35.40	.400	.833	24	2.863	.416	27.79	.299	.459
5	I–16–60	23	3.496	.379	35.43	.312	.595	24	3.313	.651	39.88	.429	.608
6	I–16–33	19	4.432	.433	43.74	.462	.811	20	4.095	.739	42.55	.522	.736
7	I–16–14	13	4.362	.451	34.46	.416	.798	23	3.709	.646	42.57	.539	.719
8	I–16–13	18	3.956	.412	30.06	.318	.674						
9	I–16–44	15	4.193	.454	41.87	.506	.741	21	3.967	.609	42.10	.542	.735
10	I–16–8	12	4.308	.434	40.67	.491	.722	22	3.618	.627	43.00	.495	.671
11	I–16–3	13	4.800	.492	37.69	.580	1.025	21	3.771	.636	39.19	.561	.723
12	I–16–45	13	4.131	.468	34.08	.412	.768	13	3.477	.652	36.31	.497	.654
13	II–16–131[a]	17	3.859	.422	32.35	.378	.634	15	5.087	.800	41.87	.539	1.103
14	I–16–2							24	3.333	.551	28.29	.381	.616
15	I–16–31	16	4.238	.470	35.25	.426	.852	19	3.089	.610	37.00	.378	.487

[a] Two-rowed varieties.

Considering first the 6-rowed barley selections (Table 2), it is evident that the data here presented do not corroborate the finding of Moldenhawer with respect to relation of number of vascular

bundles to lodging. Both the greenhouse and the field material show the nonlodging forms to possess no more and in several instances a smaller number of vascular bundles than the lodging forms. In general, the sorts with the largest number of bundles are found about midway between the lodging extremes.

It should be noted that there is not a very close correspondence between the field-grown material and that grown under greenhouse conditions. The latter also proved to be considerably more variable than the former.

None of the other characters (Table 2), average diameter of culms, average thickness of culm wall, average total area of bundles, and average area of the sclerenchyma near the periphery of the culm, show a marked relation to lodging. As an index the above characters fail to indicate with any degree of accuracy which are the nonlodging forms. The evidence points to the possibility of quality rather than quantity of strengthening tissue as the important factor in determining which forms will stand up.

What has been mentioned about the 6-rowed barleys likewise applies to the 2-rowed sorts. No morphological character which may be used as an index to lodging is apparent from the data presented.

From an examination of the oat sorts for which there are three years' data on lodging, it is apparent (Table 3) that strain I–15–40, which is a large Garton variety, contains more bundles and a larger area both of sclerenchyma and bundles than the other two strains, Department No. 5168 and Swedish Select. However, when the average culm diameter of I–15–40 is taken into consideration the significance of the differences just mentioned becomes questionable, particularly in view of the fact that strain I–06–28, Department No. 5168, altho possessing a stiffer straw than strain I–15–90, Swedish Select, has a somewhat smaller number of bundles, less sclerenchyma, and less bundle area. It should be noted that Department No. 5168 is a short, low-yielding strain which matures somewhat earlier than the other two varieties. More data are needed to answer this question satisfactorily. Oat sorts I–17–72, I–17–40, and I–17–70, for which there are but one year's data on lodging available, show practically no correlations between lodging and the above characters. The first and last strains are Sixty-Day selections and I–17–40 is a selection made from S. P. I. No. 33644, also an early oat. In the plant rows I–17–72 was noticeable because of its stiff straw when other forms, such as I–17–70, lodged very badly. It may be of interest to point out here that of these two Sixty-Day selections the

one with the stiffer straw possesses thicker walled sclerenchyma cells (see Plate 6, figure 2). No. 1–17–72 also has the thicker culm wall.

TABLE 3.—*Average data recorded on culm measurements of oats, wheat, and rye.*

Nursery selection No.	Rank as non-lodgers.	Field material measured at bottom internode[a]						Greenhouse material measured at 5th internode					
		Number of individuals	Diameter of culms	Thickness of culm walls	Number of bundles	Total area of bundles	Area of scleren-chyma	Number of individuals	Diameter of culms	Thickness of culm walls	Number of bundles	Total area of bundles	Area of scleren-chyma
Oats:			*mm.*	*mm.*		*sq mm*	*sq.mm*		*mm.*	*mm.*		*sq mm.*	*sq.mm.*
I 15 40	1	19	5.132	0.567	44.42	0.704	1.207	19	4.437	0.879	42.16	0.509	0.879
I-06-28	2							24	2.979	.684	25.00	.332	.533
I-15-99	3	14	4.364	.479	33.86	.536	.878	16	3.463	.749	26.19	.348	.662
I-17 72	1							21	3.143	.712	25.38	.337	.563
I-17-40	2							18	3.350	.614	34.80	.388	.539
I-17-70[a]	3	18	3.250	.345	20.89	.277	.503	21	3.200	.514	26.62	.316	.514
Winter wheat.													
I-01-3	1							8	2.688	.318	24.38	.266	.415
I-03-68	2							9	2.744	.512	28.00	.301	.572
Winter rye								10[c]	3.870	.516	29.80	.366	.948
Spring wheat:													
II-06-39[b]	1	19	3.616	.451	28.47	.355	.605						
Check[c]	2	14	3.007	.504	26.93	.315	.592						

[a] Strain No 1–17–70 measured at third internode, the other oats at the fourth internode

[b] Measured at third internode.

[c] Measured at fourth internode.

As winter wheat and spring wheat are each represented by but two sorts, trustworthy conclusions cannot be drawn from so few data. However, the evidence does show the more nonlodging form of spring wheat to have a slightly larger number of vascular bundles, greater average area of sclerenchyma, and a somewhat greater average total area of bundles. In the case of winter wheat these conditions are just reversed. Of the two winter wheats, Odessa and Turkey, the former has a stiff straw, while the latter lodges badly.

Winter rye, the least lodging form, shows a higher proportion of sclerenchyma area to average area of bundles than any of the cereal strains studied. Considering only the greenhouse material the absolute average area of sclerenchyma of the rye ranks second, barley strain II–16–131, a 2-rowed sort, being the only one to surpass it in this respect. The large sclerenchyma area of the latter loses some

of its significance when size of culm is taken into consideration. Selection II–16–131 possesses the largest clum of all the material grown in the greenhouse.

RELATION OF DIAMETER OF CULM TO NUMBER OF VASCULAR BUNDLES.

In general the cereals studied show no consistent correlation either between lodging and number of bundles or between lodging and diameter of culms. In order to determine whether there was some relation between diameter of culm and number of bundles for the different varieties, graphs were prepared. It would be reasonable to expect culms with a large diameter to contain more bundles than those with smaller diameters. This was found to be the case.

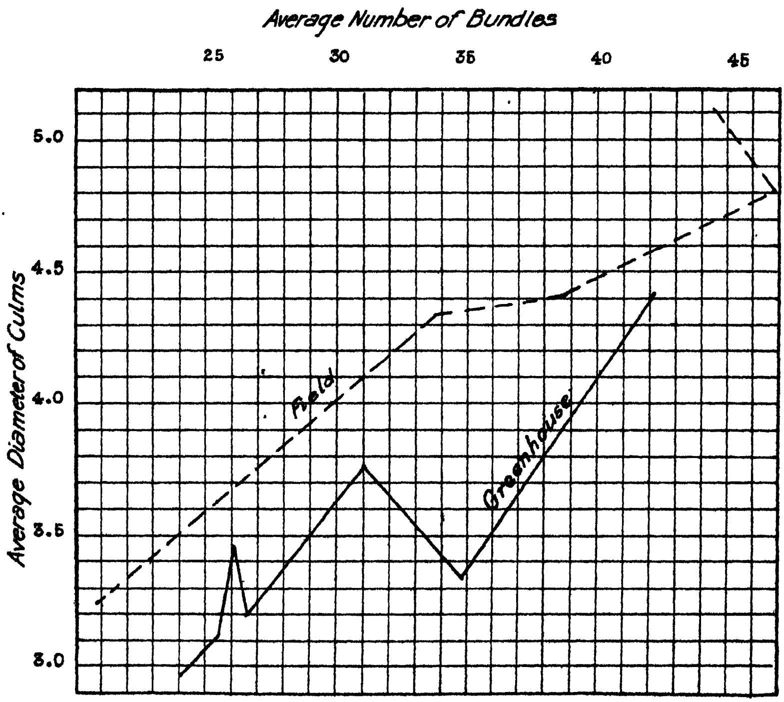

FIG. 13. Frequency graphs showing relation between diameter of culms and number of vascular bundles in oats. Measurements of greenhouse material were taken at the fifth internode, and those of field material at the fourth internode.

The graphs (figure 13) show the relation between average diameter of culm and average number of bundles for the different oat varie-

ties studied. The field-grown material shows an especially high correlation between these two characters. With culms of large average diameters there is associated a large number of bundles. This condition is, perhaps, to be expected because from a purely physical standpoint the varieties with a large culm diameter and hence considerable culm wall have more tissue in which bundles may develop than those varieties which have less culm wall. The oats grown in the greenhouse, likewise, show correlation between diameter of culm and number of vascular bundles. Here there is more fluctuation, as is brought out by the graph, but still a strong correlation is evident.

The graphs (figure 14) of the relation between mean culm diameters and mean number of bundles for the different varieties of barley show, both in the material grown in the greenhouse and that grown in the field, considerable irregularity. Even tho the graphs fluctuate a great deal, they show a distinct correlation between these two characters.

From the foregoing observations it seems that among different varieties, diameter of culm is the most important factor in determining the number of vascular bundles.

RELATION OF LENGTH OF LIGNIFIED CELLS TO LODGING

As has been stated, a maceration study was made to determine if there was a significant difference between length of lignified cells found in the lodging and nonlodging strains. From the data presented in Table 4, it is evident that there are no striking differences between the various strains of the same kind of cereal and small differences even between the different kinds. There is an indication that winter wheat possesses longer lignified cells than the other cereals.

Taking into consideration the spread of the frequency distributions the difference between the means is small. The extreme difference between the various strains of barley is only 1.81 units. A significant difference (4x the P. E.) based on 105 measurements of barley sort I–16–8 is about 1.8; thus it is seen that this standard gives but two differences which are barely significant among the barleys. Granting that these differences are real, it is evident that they possess no value as an index to lodging. The barley strains ranking one and two as nonlodgers likewise represent the longest and shortest strains, respectively. Similarly, the other possibly significant difference is found between the two sorts which lodge most.

The oats, rye, and winter wheat likewise show an inconsistent relation between length of lignified cells and lodging.

TABLE 4.—*Frequency distribution study of length of lignified cells in oats and barley grown in the greenhouse (measurements at fifth internode).*[a]

Nursery selection No	Variety.	Rank as non-lodgers	7	10	13	16	19	22	25	28	31	34	Total	Averages.[b]
Barley:														
II-16-116	Manchuria X Svanhals	1	1	4	10	18	11	5	1				50	16.24
II-16-77	S. African X Manchuria	2	2	11	31	17	7	6	1				75	14.43
I-16-15	Servian	3		5	22	6	9	4	2	1	1		50	16.02
II-16-78	Bohemia X Manchuria	4	1	5	18	13	8	3	2				50	15.20
I-16-60	Chicago No. 63 ..	5	1	8	11	13	10	5	2				50	15.56
I-16-33	Lake City	6	1	6	12	17	7	6	1				50	15.84
I-16-14	Trebi	7		6	15	18	7	2	2				50	15.38
I-16-8	Featherston	10	4	20	24	33	13	4	4	3			105	15.10
I-16-45	Scotch 20816	12	1	7	14	16	7	5					50	15.24
II-16-131	Svanhals X 2r/6r	13	1	10	13	8	7	7	2		1	1	50	16.14
I-16-2	Featherston	14	2	10	17	12	5	3	1				50	14.44
Oats:														
I-15-40	Garton	1		6	10	19	11	4					50	16.18
I-06-28	Dept. No. 5168 ...	2		5	13	15	10	4	1	1	1		50	16.62
I-15-99	Swedish Select .	3		5	12	22	7	3	1				50	15.92
I-17-72	Sixty-Day	1[c]		10	13	11	8	7	1				50	15.40
I-17-40	S. P. I. No. 33644 ..	2[c]		7	8	12	9	9	5				50	17.26
I-17-70	Sixty-Day	3[c]		6	10	14	11	4	3		2		50	16.90
Winter rye	. . ..			1	18	15	5	5	5	1			50	16.54
Winter wheat:														
I-01-3	Odessa .	1		2	9	14	7	4	8	1	3	2	50	19.36
I-03-68	Turkey Cosgrove. ...	2		6	11	5	8	9	4	1	4	2	50	18 90

[a] The class unit is 0.0172 mm.

[b] Averages computed directly from measurements.

[c] Rank for 1918 only.

RELATION OF THICKNESS OF LIGNIFIED CELL WALLS TO LODGING.

While measurements were being taken on oat strains I-17-72 and I-17-70 a difference was observed in the thickness of their lignified cell walls, as has already been mentioned. With the aim of determining this difference a number of measurements were made under an oil immersion lens. The data collected on this character of oats are shown in Table 5 and of barley in Table 6.

All measurements were made from cell cavity to cell cavity and really included a double cell wall. Ten sections of each of the early oats were examined as to the thickness of the lignified cell walls found near the periphery of the culm and those surrounding the vascular bundles. Ten cell walls selected at random in each of these two areas of a section were carefully measured, thus making 100 readings for each strain. The other strains of oats and all of the barleys are represented by 50 readings each.

Unfortunately the thickness of the sections studied made it im-

possible to focus sharply under an oil immersion lens. However, it is felt that the measurements are sufficiently accurate for the present purpose.

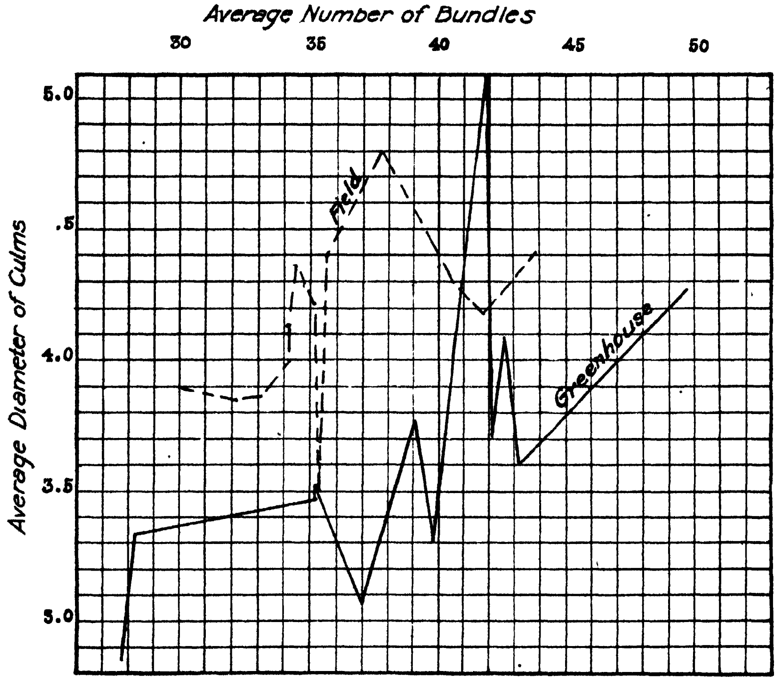

FIG. 14. Frequency distribution graphs showing relation between diameter of culms and number of vascular bundles in barley. Measurements of greenhouse material were made at the fifth internode, and those of field material at the fourth internode.

Considering the early oats (Table 5) alone in one group and the remaining three sorts in another group, it is evident that there is a positive correlation between nonlodging and thickness of sclerenchyma cell wall. This character shows a significant measurable difference, with two possible exceptions, between any two strains in favor of the more nonlodging sort. The difference between the cell walls surrounding the bundles of strains I–06–28 and I–15–99 respectively is $0.116 \pm .058$, which is only two times its probable error. The difference in thickness of cell walls in the sclerenchyma near the outside of the stem between strains I–15–40 and I–06–28 is also rather small ($0.160 \pm .066$) in view of its probable error.

In order to corroborate the above results more sections of the original material of sorts I–17–72 and I–17–70, both of which are selec-

tions from commercial Sixty-Day oats, were prepared by using a slightly modified technic from what was previously employed. Measurements were taken as before under an oil immersion lens. Again significant differences between the thickness of sclerenchyma cell walls in favor of the more nonlodging sort was obtained. Lignified cell walls near the outside of culms showed a difference of 1.055 ± .075, while those which surrounded the bundles showed a difference of 0.480 ± .048.

Differences in thickness of lignified cell walls between sorts I–17–72 and I–17–70 are also brought out in Plate 6, figure 2.

From the evidence presented it is reasonable to expect that in oats the character, thickness of sclerenchyma cell wall, may facilitate the immediate segregation of the more nonlodging forms. Further evidence on this point is being sought.

TABLE 5.—*Thickness of lignified cell walls of oats grown in the greenhouse. (Data are averages of ten readings taken at the fifth internode.)*[a]

	Sclerenchyma near periphery of stem.						Sclerenchyma around bundles.					
	Early oats.			Medium oats.			Early oats.			Medium oats.		
	I–17–72.	I–17–40.	I–17–70.	I–15–40.	I–06–28.	I–15–99.	I–17–72.	I–17–40	I–17–70.	I–15–40.	I–06–28.	I–15–99.
	2.75	2.03	1.25	2.63	2.75	2.38	2.25	1.40	1.25	2.28	2.10	1.83
	2.58	1.90	1.10	2.40	2.23	2.10	1.80	1.50	1.30	2.15	1.90	1.68
	2.30	1.90	1.15	2.45	2.30	1.78	1.80	1.40	1.25	2.20	1.98	1.60
	2.05	1.93	1.23	2.60	2.03	1.88	1.85	1.60	1.05	2.20	1.48	1.95
	2.30	1.83	1.00	2.48	2.45	1.88	1.90	1.65	.95	1.90	1.88	1.70
	2.60	1.88	1.08				1.70	1.50	1.10			
	3.25	1.73	1.08				2.50	1.50	1.20			
	3.33	1.68	1.50				2.15	1.45	1.00			
	3.30	2.08	1.55				2.20	1.50	1.10			
	3.08	1.78	1.48				2.30	1.50	1.15			
Total	27.54	18.74	12.42	12.56	11.76	10.02	20.45	15.00	11.35	10.73	9.34	8.76
Average ...	2.754	1.874	1.242	2.512	2.352	2.004	2.045	1.50	1.135	2.146	1.868	1.752
P. E. of averages..	.046	.032	.026	.048	.046	.043	.022	.023	.027	.047	.047	.034

[a] The unit is 0.00155 mm.

Similarly, measurements were taken on the barley strains, but with different results, as may be seen by examining Table 6. Neither the thickness of the lignified cell walls found near the periphery nor those near the bundles show a consistent correlation with the relative ability of the sort to stand up. Thickness of cell walls in the sclerenchyma

of barley shows much fluctuation. A difference of only 0.110 in this character was found in the sclerenchyma near the outside of the culm between the average of the strains ranking 2 to 9 inclusive as to nonlodgers and 10 to 15 inclusive. These same two groups differed by 0.078 with respect to thickness of lignified cell walls surrounding the bundle. The comparatively small differences, together with the fluctuations already mentioned, made it impossible to pick out with any degree of certainty the nonlodging strains of barley. It is barely possible that thinner sections which could be measured more accurately under an oil immersion lens would reveal differences similar to the oats, but in a much less degree.

TABLE 6.—*Thickness of lignified cell walls of barley grown in the greenhouse. (Data are averages of ten readings taken at the fifth internode.)*[a]

SCLERENCHYMA NEAR PERIPHERY OF STEM.

Selection numbers.	II-16-77.	I-16-15	II-16-78.	I-16-60	I-16-33.	I-16-14.	I-16-44	I-16-8.	I-16-3	I-16-45.	II-16-131.	I-16-2.	I-16-31.
Rank as non-lodgers	2	3	4	5	6	7	9	10	11	12	13	14	15
	2.45	2.05	1.63	1.75	1.20	2.58	1.80	1.85	2.50	2.35	1.33	1.78	1.90
	2.13	1.75	1.95	1.85	1.68	2.33	2.23	1.60	2.40	2.45	1.35	1.83	2.00
	2.65	2.05	1.78	1.98	2.08	2.53	2.23	1.93	2.23	2.55	1.20	1.93	1.70
	1.85	2.75	1.48	2.10	1.45	2.25	2.20	1.50	1.90	2.50	1.15	1.83	1.98
	1.80	2.45	1.25	1.60	1.20	2.38	2.10	1.95	1.43	2 48	1.25	1.75	1.70
Total . . .	10.88	11.05	8.09	9.28	7.61	12.07	10.56	8.83	10.46	12.33	6.28	9.12	9.28
Average . .	2.175	2.21	1.618	1.856	1.522	2.414	2.112	1.766	2.092	2.466	1.256	1.824	1.856

SCLERENCHYMA AROUND BUNDLES.

	1.60	1.25	1.30	1 33	1.20	1.58	1.43	1.25	1.50	1.25	1.20	1.33	1.23
	1.70	1.10	1.20	1.23	1.25	1.70	1 40	1.23	1.28	1.40	1.13	1.35	1.23
	1.60	1.15	1.40	1.18	1.20	1.43	1.30	1.20	1.35	1.35	1.18	1.20	1.13
	1.58	1.45	1.23	1.53	1.15	1.53	1.40	1.13	1.33	1.40	1.25	1.25	1.20
	1.38	1.20	1.15	1.23	1.05	1.43	1.23	1 30	1.23	1.45	1.28	1.13	1.28
Total	7.86	6.15	6.28	6.50	5.85	7.67	6.76	6.11	6.69	6.85	6.04	6.26	6.07
Average . . .	1.572	1.23	1.256	1.30	1.17	1.534	1.352	1.222	1.338	1.37	1.208	1.252	1.214

[a] The unit is 0.00155 mm.

CONCLUSIONS.

Extreme varieties for lodging in wheat, oats, and barley, were selected for this study, and measurements were also made of Minne-

sota No. 2 winter rye, which stands up better than the other cereals. A study was made of the correlation between lodging behavior and average size of culm, average number of bundles, average area of sclerenchyma, thickness of culm wall, length of lignified cells, and thickness of lignified cell wall. None of the above-mentioned characters except thickness of cell wall seems closely related to lodging.

Both the early and medium oat strains examined showed a distinct correlation between thickness of lignified cell walls and lodging.

In general, lodging in cereals is dependent on so many factors of unequal value in the different sorts that no one factor seems to be correlated closely enough with lodging to be of much value as a selection index.

Among the different strains of oats and barley, average number of vascular bundles was found to be correlated with average diameter of culms.

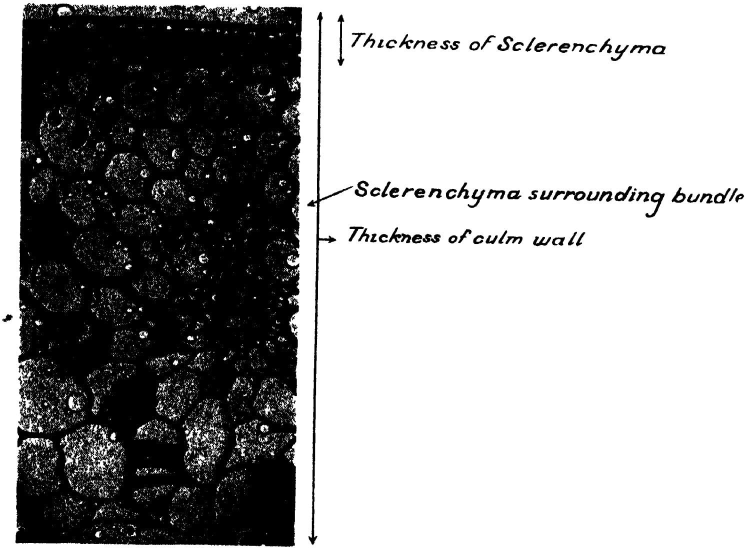

FIG. 1. Cross-section of barley strain I-16-2, showing some of the measurements taken. The defects which appear like air bubbles were due to globules of celloidon which were not entirely removed by the ether treatment.

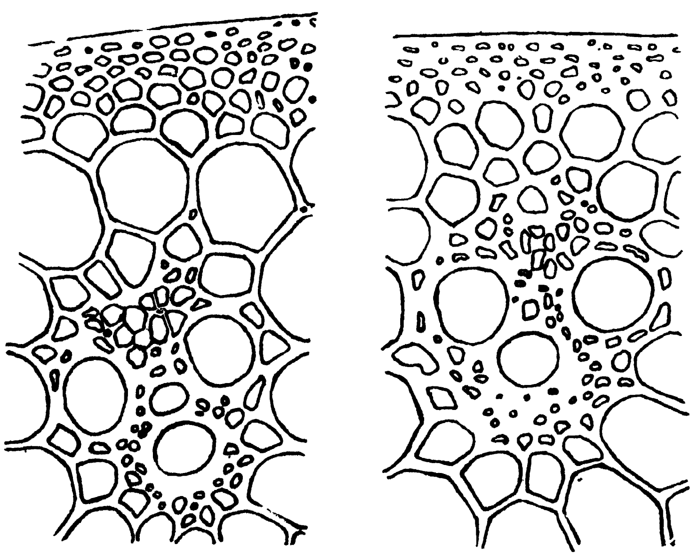

FIG. 2. At the left, cross-section of oat strain I-17-70, a lodging form of Sixty-Day. At the right, cross-section of oat strain I-17-72, a non-lodging form of Sixty-Day. Note the thicker walled cells of the sclerenchyma tissue both near the periphery of the stem and around the bundle as compared with I-17-70.

KOTA, A RUST-RESISTING VARIETY OF COMMON SPRING WHEAT.[1]

L. R. WALDRON AND J. A. CLARK.

Resistance to stem rust of wheat (*Puccinia graminis tritici*) is a quality lacking among the varieties of common spring wheat now grown commercially in the hard spring wheat sections of the United States. Following the introduction of the Marquis variety, claims were made for its rust resistance, but further tests showed that it merely escaped rust.

True resistance, however, has long been recognized in many varieties of durum wheat. The introduction of the durum wheats, and later of the Marquis, into the hard red spring wheat region were epoch-making events. These wheats won their way almost entirely because of their increased yield over the varieties already in cultivation, the increase being due in large measure to the relation of the wheats to stem rust. The durums were resistant and the Marquis evaded rust by ripening early.

In an endeavor to originate a rust-resistant variety of common spring wheat, resistant varieties of durum wheat have been crossed with commercial varieties of common wheat. This, apparently, afforded the most practical means of obtaining the desired end. Results up to the present, however, have not been very successful. No high-yielding hybrid of common wheat having the rust resistance of the durum and the good milling and baking qualities of Marquis has yet been originated.

The authors believe that the Kota, the variety of common wheat here discussed, possesses the rust resistance sought. It also gives promise of being a high yielding and an excellent bread-making wheat. If the variety does not in itself possess all of these qualities, it is hoped that its discovery will obviate the necessity for further crossing durum and common wheats in breeding for rust resistance.

HISTORY.

Kota wheat first came to the attention of the authors in 1911, when they were located at the Dickinson Substation, Dickinson, N. Dak.

[1] Joint contribution from the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak., and the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication April 4, 1919.

The station that year received from Prof. H. L. Bolley, biologist of the North Dakota Agricultural College, samples of four durum wheats designated by him as D-1, D-4, D-5, and D-7. These were first grown in 1911 and because of high yield the D-1 was continued in the experiments at Dickinson. It was given the name of Monad by Ball and Clark[2] in 1918. The Monad is one of 25 lots of wheat introduced from Russia in November, 1903, by Professor Bolley, who in that year made a study of the flax industry in Europe for the United States Department of Agriculture. These varieties were introduced as Foreign Seed and Plant Introduction Nos. 10194 to 10218.

When introduced at Dickinson the Monad contained an admixture of about 25 percent of a bearded common spring wheat, as evidenced by a sample of the 1911 crop on storage at the experimental mill. As no intensive work was undertaken with the Monad wheat at that time no attempt was made to purify it, other than the annual rogueing of the plots. In the rust epidemic of 1916, the Monad variety proved to be extremely rust resistant. It yielded at the rate of 26.2 bushels per acre, or 8.8 bushels more than the next highest yielding durum variety, and 12.7 bushels per acre more than Marquis. In studying head samples from this plot after harvest the authors discovered independently that the common wheat which was still mixed with it also showed evidence of rust resistance. As a result of these observations, separations of the common wheat were made in 1917 and to these the name Kota has now been applied. The name is a shortening of the latter part of the State name, North Dakota. It has been given Cereal Investigations No. 5878 by the Office of Cereal Investigations of the United States Department of Agriculture and No. 10003 by the North Dakota Agricultural Experiment Station.

This wheat may have been one of Professor Bolley's original introductions, but it is now impossible to associate it with its proper Seed and Plant Introduction numbers. It is very similar in appearance, however, to his R. B. R. 3.

Description.

The description of the Kota variety is as follows:

Plant spring habit, midseason, midtall; straw white, strong; peduncle straight, hollow; spike awned, fusiform, middense (40 to 55 mm. per 10 nodes); glumes glabrous, white, midlong, midwide; shoulders midwide, square to elevated; beaks narrow, 3-20 mm. long; awns white, 5-8 cm. long; kernels dull red, midsized, ovate, slightly humped; germ area small; crease wide, usually shallow; cheeks usually rounding, brush short.

[2] Ball, Carleton R., and Clark, J. Allen. Experiments with durum wheat. U. S. Dept. Agr. Bul. 618, p. 44. 1918.

Among the pure lines selected there are some slight variations in kernel type. About 30 percent of the selections have slightly longer and narrower kernels, which somewhat resemble those of the Crimean group of hard red winter wheats. At least one of the selections has soft kernels and several have distinctly angular cheeks. There is little variation in the spike characters among the different pure lines. The variety can be distinguished from Preston ("Velvet Chaff"), the variety it most closely resembles, by longer beaks on the outer glumes and by the distinctly elevated shoulder (see Plate 7, figure 1). Two strains of Preston were among the original separations made, but they were easily recognized by these characters and their susceptibility to rust.

YIELD.

Yield data have been obtained in only one season, 1918, and at one place, Fargo, N. Dak., and only for the mass variety. Meager as these results are, it seems desirable to present them.

A number of wheat varieties were sown in 17-foot rows, replicated five times. The yield and rust data recorded are given in Table 1.

TABLE 1.—*Acre yield in bushels of 17 varieties of spring wheat grown at the North Dakota Agricultural Experiment Station, Fargo, N. Dak., in 1918, with percentage of stem-rust infection on each.*

Class and variety.	C. I. No.	Yield per acre.	Rust infection.	Class and variety.	C. I. No	Yield per acre.	Rust infection.
		Bushels.	*Percent.*			*Bushels.*	*Percent.*
Durum:				Common, con'd:			
Monad	3320	35.96±0.64	5	Power Fife, N. Dak. No. 920		25.55± .91	65
Mindum ...	5296	34.48±1.41	10–15	Red Fife	3329	24.71± .74	65
Kubanka ..	4063	33.00±1.21	25	Power Fife...	3697	23.28±1.11	65
"D–5"	3322	31.61±1.44	0– 5	Red Bobs....		20.41± .53	65
Arnautka ..	1494	29.28± .71	25	Preston	3328	19.97±1.00	65
Buford	5295	27.21±1.68	15–20	Ghirka Spring	1517	19.85± .44	65
Common:				Haynes Bluestem	3020	19.52±1.31	65
Kota	5878	29.53± .74	10–15	Ruby........	6047	18.70± .91	25–40
Marquis ...	3641	29.33± .90	25				
Kitchener ..	4800	26.90±1.01	65				

The six durum varieties (Table 1) show an average yield of 31.92 bushels per acre, while the 10 common wheats, not including Kota, averaged but 22.82 bushels per acre. The Kota wheat yielded 29.53 bushels, slightly less than the average for the durums. Marquis yielded 29.33 bushels, practically the same as Kota. The durum yields varied considerably, ranging from 27 bushels for Buford to 36 bushels for Monad.

Comparative yields were secured also from larger plots of several varieties. The grain was sown with a garden drill in rows 1 foot apart. The plots were of various sizes, most of them being larger than a hundredth acre. The following tabulation gives the results:

Group or variety.	No. of plots.	Yield, bushels per acre.
Durum	7	31.62 ± 1.17
Power and Red Fife	5	21.74 ± 1.00
Marquis	3	21.48 ± 1.12
Bluestem	2	20.38 ± .77
Preston	1	18.15
Kota	1	28.40

Here again, the durums outyielded the other wheats, but the Marquis yielded less than Power of Red Fife. The yield of Kota is decidedly higher than any of the other hard red spring wheats and is only 3 bushels below the durum yields. No rust notes were taken on these wheats.

Rust Resistance.

DATA FROM NURSERY EXPERIMENTS.

In 1917 the senior author selected 48 heads of the common wheat from the Monad variety grown at Fargo, N. Dak., in addition to the composite sample used in the experiments just discussed. The seeds from these were grown in head rows at Fargo in 1918. Two of these selections proved to be Preston, so there were only 46 head rows of Kota.

The junior author also made head selections of the common wheat from the Monad variety grown at the Judith Basin Substation, Moccasin, Mont., in 1917. Ten of these selections were sent to the experiment stations at Brookings and Highmore, S. Dak., and Manhattan, Kans., and twenty to University Farm, St. Paul, Minn. The results of these preliminary trials have revealed rust resistance far in excess of that of other common spring wheats.

At Fargo, N. Dak., the 46 pure lines of Kota had stem-rust infection varying from 5 to 15 percent. The percentages of rust infection on the 46 head rows were distributed in groups as follows:

Stem-rust infection in percentage groups	—5	5	5–10	10	10–15
Number of head rows in each group	4	18	16	4	4

The mean rust infection for these Kota strains is 6.74 percent. The two head rows of the Preston type showed rust infection of 45 and 65 percent, respectively, while two adjacent head rows of durum

wheat showed 5 and 40 percent. Several rows of Power Fife, sown in a depression in the plot, showed 40 to 65 percent of infection.

The mean rust infection on 6 varieties of durum wheat, as shown in Table 1, is 14.6 percent, the infection ranging from less than 5 percent in the red durum, "D–5," to 25 percent in Kubanka and Arnautka. The Marquis and Ruby wheats, notwithstanding their early maturity, showed 25 percent or more of rust infection. The other wheats, except the Kota, were heavily infected. The mass-selected Kota was recorded as having from 10 to 15 percent of rust.

At Brookings, S. Dak., the ten pure lines of the Kota showed rust infection of 20 percent, compared with 40 to 65 percent infection on other common wheats, and as low as 10 percent on the most resistant durums.

At St. Paul, Minn., eight pure lines grown in the cereal rust nursery. Six had rust infections of 15 percent. Two proved susceptilbe to rust, both having an infection of 80 percent. In the same nursery, durum wheats were infected from 1 to 70 percent, and common wheats from 70 to 100 percent. In this nursery a rust epidemic was artificially produced. The nursery included 820 varieties and strains of domestic and foreign origin. The six resistant strains above mentioned, together with two apparently identical strains selected by Mr. John H. Parker, were more resistant than any other common spring wheats, except three unadapted foreign varieties. In the agronomy breeding nursery, with only natural rust infection, five pure lines of Kota had infections ranging from 0 to 10 percent.

At Highmore, S. Dak., and at Manhattan, Kans., where ten pure lines of the Kota were grown, absence of rust prevented the making of any comparisons.

The data recorded on 67 out of 69 pure lines show that the Kota was much more resistant to the attacks of the form or forms of wheat stem rust present in 1918 at Fargo, N. Dak., Brookings, S. Dak., and St. Paul, Minn., than were the other hard red spring wheats. The percentage of infection was only slightly greater than the average for the durum varieties.

It will be noted that the Monad variety, from which Kota was separated, is resistant, but is exceeded in this respect by the red-kerneled durum wheat, "D–5." The suggestion has been made that Kota wheat may have originated from a natural field hybrid between a common wheat and Monad (D–1), D–5, or some other durum wheat. Accurate knowledge of the histology and morphology of such

hybrid forms is very meager. A close study of Kota wheat, with a more extended study of known hybrids, ought to lead to definite conclusions.

DATA FROM GREENHOUSE INOCULATION EXPERIMENTS.

Dr. E. C. Stakman, collaborating pathologist at the Minnesota Agricutural Experiment Station, has conducted rust inoculations on the bulk Kota wheat and the Monad durum, which field observations in North Dakota have shown to be a rust-resistant wheat. He has very kindly furnished us these data in advance of publication. In coöperatiove experiments with the Office of Cereal Investigations, Doctor Stakman and his coworkers[8] have isolated different biologic forms of *Puccinia graminis tritici*. It has been found that these forms have different geographic distributions, within certain limits. The data presented include results of rust inoculations from rust spores collected in various parts of the United States. Different biologic forms undoubtedly are represented in the list, but certain forms no doubt are duplicated. The data are presented in Table 2. The scale of infection is as follows:

0. No infection.
1. Minute uredinia with some hypersensitiveness.
2. Moderate uredinia with some hypersensitiveness.
3. Moderate uredinia and no hypersensitiveness.
4. Heavy normal infection.

The plus, minus, double plus and double minus indicate intermediate degrees.

The degree of correlation existing between the results obtained in the greenhouse and the natural infection taking place in the field, using the same hosts and the same forms of the parasite, is yet unknown. A study of the results shows considerable variation in the amount of infection on the Kota and less variation on the Monad. The amount of infection on the Kota, using the data where they are comparable, is distinctly less than on the Monad. The fact that the Kota reacts positively to rust collected at several points in Minnesota and North Dakota is puzzling, in view of its field behavior at Fargo, N. Dak. The natural assumption is that certain biologic forms of rust, to which Kota wheat is susceptible, exist in part of North Dakota, but have not been present at Fargo. Such a fact would be, *a priori*, somewhat

[8] Stakman, E. C., Levine, M. N., and Leach, J. G. New biologic forms of *Puccinia graminis*. *In* Jour. Agr. Research, v. 16, no. 3, p. 103–105. 1919.

surprising, considering the topography and rather uniform climatic conditions of the State.

TABLE 2.—*Degrees of rust infection obtained at University Farm, Minn., on Kota and Monad wheat, using spores from various localities.*

Rust series No.	Source of rust-spores.	Degrees of stem-rust infection on—		Rust series No.	Source of rust-spores.	Degrees of stem-rust infection on—	
		Kota.	Monad.			Kota.	Monad.
66*a*	Ainsworth, Nebr....	1+		39	Grand Forks, N. Dak.	3−	3+
66*b*	do	4		37	Minneapolis, Minn..	3	3
96	Alton, Iowa		3+	65	Oklee, Minn.	3+	3
8*a*	Baton Rouge, La. .	3=		79	Powers Lake, N. Dak.	4−	
2	Brundidge, Ala. ...	0	3++	129	Presque Isle, Maine		
30	Clearspring, Minn...		3=	1	St. Paul, Minn.	3+	
5	Corvallis, Oreg.	0	4	4	Stillwater, Okla.....	3+	3
136	Denver, Colo. . .			143	Towanda, Kans....	0?	
26	Fairmount, Nebr. ..		3+	17	Valdosta, Ga.	0?	3+

Inoculation studies were made on several head rows of Kota wheat at Manhattan, Kans., during the winter of 1918–19 by Prof. L. E. Melchers, who has kindly furnished some of the data in advance of publication. Professors Melchers found the Kota wheat to be susceptible to *P. graminis tritici inficiens* Melchers & Parker.[4] This biologic form has been found to develop normally on seedlings grown in the greenhouse of the three hard red winter wheats, Kanred, P1066, and P1068, which are resistant to the rust form *P. graminis tritici,* as is Kota also. Aside from the difference of spring and winter habit, the Kota and Kanred wheats seem to be closely allied morphologically.

Professor Melchers' general conclusions are as follows:

The inoculations with *Puccinia graminis tritici-inficiens* were made in the seedling stage. Checks accompanied each series inoculated. Selections of Kota, when inoculated with *Puccinia graminis tritici-inficiens,* prove to be quite susceptible. Infection is usually heavy, uredinia numerous and generally from .5 mm. to 1.5 mm. in size. The only differences between this variety and any other susceptible variety of *Triticum vulgare* is the rather consistent production of medium to small uredinia.

MILLING AND BAKING RESULTS.

Samples of the bulk Kota wheat and of six other varieties grown at the North Dakota Agricultural Experiment Station have been milled and the flour baked in the milling and baking laboratory of the

[4] Melchers, L. F., and Parker, John H. Another strain of *Puccinia graminis.* Kans. Agr. Expt. Sta. Cir. 68, 4 p. 1918.

Bureau of Markets, Washington, D. C. The results obtained are given in Table 3. Photographs of a loaf of bread made from flour of Kota wheat and a series of loaves made from flour of each of the varieties milled are shown in Plate 7, figures 2 and 3.

TABLE 3.—*Milling and baking data on 7 varieties of wheat grown at the North Dakota Agricultural Experiment Station, Fargo, N. Dak., in 1918.*[a]

Variety.	C. I. No.	Lab. No.	Bushel weight.		Screenings.	Moisture content.			Crude protein (N × 5.7).	
						Wheat.				
			Before cleaning.	After cleaning.		Before tempering.	After tempering	Flour.	Wheat.	Flour.
			Lbs.	*Lbs.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Marquis	3641	4790	59.8	60.3	5.5	11.5	15.0	12.5	15.3	14.2
Kota	5878	4788	61.0	62.0	2.8	11.4	15.0	11.8	13.8	12.9
Power Fife	3697	4789	59.2	60.5	4.9	11.4	15.0	12.5	14.3	13.2
Preston	3081	4795	60.5	61.0	5.2	12.3	15.0	12.1	14.9	13.6
Haynes Bluestem	2874	4799	57.0	58.3	2.9	10.9	15.0	12.4	15.3	13.9
Kubanka No. 8	4063	4797	61.0	60.3	6.3	11.5	15.0	11 5	13 3	12.8
Monad	3320	4791	61.1	61.2	3.6	11.8	15.0	10.6	12.8	12.0

Variety.	Milling results.				Baking results.					
						Loaf.				
									Color.	
	Flour.	Bran.	Shorts.	Loss.	Absorption of water.	Volume	Weight.	Texture.	Score	Shade
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*c.c.*	*gm.*	*Per cent*	*Per cent*	
Marquis	73.6	15.5	11.5	.6[b]	59.1	2,950	482	91.5	95.5	Slightly creamy gray
Kota	69.4	13.5	15.0	1.5	63.2	2,910	488	94 5	94.0	do
Power Fife	73.5	14.0	12.5	0	60 6	2,590	487	90.5	91.5	do
Preston	71.5	14.6	11.7	2.2	59.7	2,470	483	90 0	92.0	do
Haynes Bluestem	72.5	15.6	10.8	1.1	60.6	2;330	493	90.0	91.0	do
Kubanka No. 8	72.8	11.6	13.6	2.0	59.1	2,390	487	96.5	94.0	creamy gray
Monad	68.3	14.2	14.1	3.4	59.7	2,210	485	95.5	90.0	do

[a] Data obtained by the Office of Cereal Investigations, Bureau of Plant Industry, in cooperation with the Bureau of Markets, United States Department of Agriculture.

[b] Gain.

The data show the Kota variety to be a good milling and an unusually good bread wheat when compared with standard varieties. The wheat is comparatively high in weight per bushel, but somewhat low in yield of flour. The flour is high in absorption and the loaf

FIG. 1. Head, glumes and kernels of Kota wheat

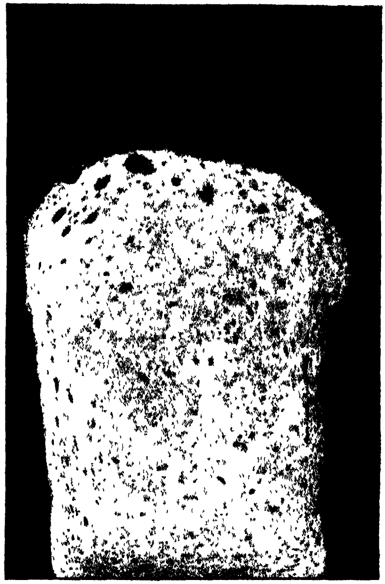

FIG. 2. Loaf of bread baked from 340 grams of flour of Kota wheat Average volume of loaf, 2,910 c.c.

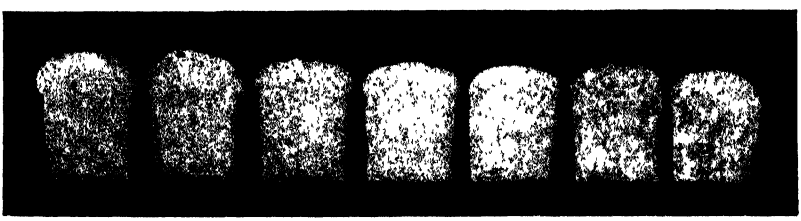

FIG. 3. Seven loaves of bread from varieties of wheat grown at Fargo, N. Dak. The varieties, with the average loaf volume, are as follows (left to right): Marquis, 2,950 c.c.; Kota, 2,910 c.c.; Power Fife, 2,590 c.c.; Preston, 2,470 c.c.; Haynes Bluestem, 2,330 c.c.; Kubanka No. 8, 2,300 c.c.; Monad, 2,210 c.c.

ranks high in volume, weight, texture and color. The crude protein content is lower than in the other common wheats included in this experiment, but ranks far above the average for the class of common hard red spring wheats. The high weight per bushel and low yield of flour are similar to that found in Preston, which is a bearded common wheat. The large expansion shown by the loaf volume and the texture of the loaf, however, indicate that the variety is superior to Preston as a bread wheat, and also to Power Fife and Haynes Bluestem, and that it is equal to Marquis (see Plate 7, figures 2 and 3).

The flour from the Kota wheat is granular, much like durum wheat flour, and is relatively low in volume compared with flour from other common wheats. In milling the wheat it was observed that it was about half way between common and durum wheat in hardness. The strength of the gluten revealed by the large loaf volume, however, does not indicate any similarity to durum wheat flour.

Summary.

A variety of bearded hard red spring wheat designated as Kota (C. I. No. 5878) has been shown to possess resistance to the form or forms of the stem rust of wheat present at Fargo, N. Dak., Brookings, S. Dak., and St. Paul, Minn., in 1918. Additional evidence of such resistance was secured in 1917. This resistance is decidedly greater than that possessed by the common spring wheats and second only to the more resistant durum wheats.

Results secured at Fargo, N. Dak., in 1918 showed a capacity for yield decidedly above the average of the common wheats and only slightly less than the average yield of the durum wheats.

Milling tests conducted with Kota wheat showed it to produce somewhat less flour than the average of other wheats used in the same test. Baking tests ranked it very high as a bread wheat, as it markedly exceeded the other common wheats except Marquis, which it equaled.

OFFICIAL FIELD CROP INSPECTION.[1]

H. L. BOLLEY.

Now, when it has been forcibly brought out that the nation is vitally interested in farm results and that to get maximum production some system of efficient supervision is essential, it may not be out of place to call attention to a line of work in which official supervision would be beneficial and, for various reasons, quite essential, even under normal conditions. There is a phase of farm cropping, especially with cereals, in which the State is not only vitally interested, but could become of great aid to growers and to the consuming public. That line of work may perhaps be properly named official field crop inspection.

Great strides have been made, from the educational standpoint, in crop improvement during the past 25 years. It is apparent, however, to those who are closest to the work that improvement in cereal cropping is not nearly proportionate to the general gain in information as to possible cropping methods. There is much knowledge as to tillage, crop rotation, and seed breeding, and much improvement in farm machinery and methods of crop handling thru farm machinery; yet the processes which, from a scientific standpoint, are necessary to high yield and quality are not in common practice and, when used, are so intermittently followed as to cause failure of crop improvement that should otherwise naturally follow.

If the above is true, it is worth the attention of those of us who are specialists in certain lines of agriculture to try to determine the reasons for such failure to follow best processes and to arrive at a remedy along the lines which may result in getting the process constructively carried on.

For example, much work is done in breeding seeds. The States and Nation are at much expense to allow certain experts to study Mendelian methods of cross-breeding and other lines of work which result in the introduction of new varieties and kinds. Certain business men who are concerned with the results are not backward in saying that this introduction of varieties is often harmful rather than

[1] Contribution from the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak. Read at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 6, 1919, by Prof. J. H. Shepperd.

beneficial and those of us who are close enough to the field to note the results are perhaps willing to admit that many valuable varieties are so intermixed and jumbled as to merit such disapproval.

It is safe to say that, in cereal agriculture, varieties are not kept separate and are not handled in the same intelligent manner as that which characterizes the best fruit and vegetable growing methods. Is there any reason why this should be the case?

Again, as I have pointed out in other addresses, most agriculturists and many able farmers are convinced that crop rotation is a necessary process for best seed and crop production in cereals, yet there are few crop rotation series which are recognized for any particular region which are carried out with any consistency. There must be some general reason which accounts for such failures to apply the principles, methods, and teachings which all of us and many able farmers believe in.

I do not here wish to enter into a discussion of crop rotation, soil tillage, or purely sanitary matters of cropping, but will call attention to one phase which I think illustrates the way out, so that processes known to be necessary may be constructively continuous. I advocate a legal basis for bringing about stability and standardization of varieties in cereal cropping. I believe that there is a good excuse for official supervision of seed production and distribution.

I am not, I believe, unduly optimistic when I affirm that under properly systematized seed standardization and sanitary cropping thru means of proper handling of the soil and seed, any State or the Nation might readily lift its annual average yield of wheat several bushels per acre per year. I think that a minimum increase of 5 to 10 bushels per acre for proper systematic handling of the seed crop might not be beyond reasonable expectation. Further, I believe this would be doubly assured were it no longer possible for a man to plant the same general crop two years in succession on the same land. For the land control proposition we may not yet be ready, but certainly for the seed control proposition we have reached the stage when it is folly to claim that further improvement can be made by simple processes of education when almost all the processes of marketing and general farm procedure are so conducted as to offset any improvement that can be made by intermittent educational processes, however effectively administered. I need only call attention to the fact that there are very few new varieties of cereal which remain in reasonably pure form past the third generation on the farm and in the market. Very few of the wheats in the leading districts

survive a decade before they are replaced by some new creation which runs perhaps only a shorter, more precarious existence.

OPPOSITION TO PROGRESS.

Many of us are prone to discant on the initiative being left in the hands of the farmer and many in the business world or manufacturing side are pretty sure to decry any attempt to improve matters by the enactment of law. I am quite convinced that laws which are enacted but never put into operation are useless. I am also convinced that those which are enacted and put into operation and which remain in operation, such as the sanitary laws for the control of Texas fever and smallpox and compulsory disinfection after diphtheria, scarlet fever, etc., are laws which should have been enacted and which, because they are still in force, prove that there was a necessity for such enactment. I believe that it will be understood that many laws are enacted which do not need to be enforced. They form the educational basis for stable processes. Many good laws are self operative. Such laws remain on the books as a basis and guide for those officials whose business it is to advocate progressive advance. Such a law, for instance, is the ordinary anti-expectoration law. It was easy to make fun of it and to say that it was unnecessary and that everything could be done by education, but who among us will contend that such criticism or opposition was well founded?

Nevertheless, when we strike the matter of farming processes and indicate that there should be sanitary laws affecting farm processes, officially supervised by State officers not amenable to politics, there are many who object and say that such laws are unnecessary and that we should "rely on educational methods," indicating that too much supervision will bring about stagnation. Then there are others who are sure to call such laws sumptuary, tending to prevent individual freedom of action and toward depression of business operations.

In years past we have gone so far in this *laissez faire* line of non-control of farming matters that any approach to supervision by the State of any farming work is sure to be resented by some lines of business, even tho it meets with favor in the eyes of those whom it is intended to help. Thus, for example, few of us but can remember the strenuous efforts to resist fertilizer control lines of work, and the strong opposition to enactment of horticultural and entomological supervision for control of insect and fungous pests and to the enactment of simple seed inspection laws. Even now, in the work of plant-disease control, it is apparent that there are yet those who insist

that the State should keep out, that there should be no supervisory laws effecting control work. When, for example, but lately it was proposed that the State and Nation should attempt control of wheat rust through barberry eradication, not a few who should know much as to the reasons for the necessity of such eradication spoke out freely and feelingly in the advocacy of a campaign of education, as tho we had not had that campaign for nigh on to two centuries. And now, if one should but propose compulsory seed treatment of cereals for prevention of smut and control of scab and similar cereal diseases, or a law simply to prevent continuous cropping of the land so that there might not be a continuous accumulation of such diseases in the soil and seed of special crops, many so-called educated men would throw up their hands in feigned horror. Yet enactment of such soil and seed laws would be but a natural consequence following upon years of investigation and established knowledge relative to what should be done in order to control such cereal diseases. In other words, it would be but a natural step toward carrying out present knowledge of cereal disease control through sanitary methods so that the work done may not be continually and perpetually a loss thru the carelessness of ordinary marketing and farming processes.

I discuss this phase of the sanitary question as to soil and seed only to introduce the idea of the necessity that the States attempt by law to standardize seed quality thru proper methods of seed cropping and seed control.

I propose the thought that many of our so-called educational campaigns need a basis of equitable law. One cannot expect sanitary or proper planning to be carried out merely on the suggestion of a professor from the agricultural college or of an extension worker if the carrying out of the processes must be placed eternally upon the Utopian basis that the man who does the work may hope for some results, but whether he does or does not get them he should be and is expected to do it so that his neighbor may also prosper. Merely to recite to him that the public should have the benefit of the better crop that he will raise loses force after a time except it be backed by an emergency such as has come about under war conditions. It is too great a strain on the word loyalty to ask it, unless asked of all. In fact, the work will not be done with sufficient unanimity to give worth-while results except it be done by all continuously, year by year. The proper basis for sanitation on the farm as to crops is not different than in the home, factory, and school. It should rest on equitable law, educationally and equitably administered.

I believe that the first step in cereal crop improvement rests in a further extension of our State seed and weed laws and in the activity of the forces represented by them, to include proper control of seed crop production and of seed and grain distribution.

PRESENT STATUS OF SEED PRODUCTION, CROPPING AND MARKETING OF CEREALS.

In the line of cereal cropping and marketing we are not progressing as fast as the growth of our population calls for. The increase in population of the world, even in peace time, calls for a marked increase in cereal crop production. This increased demand has brought the total acreage of wheat in the United States close to the maximum acreage at which labor is available for its production, and, what is worse, has reached such a high annual acreage in the chief regions of wheat culture that it is becoming extremely difficult to plan a rotation which will give sufficient improvement in the sanitary status of the soil as to allow of seed improvement. In spite of our knowledge in the matters of sanitary cereal cropping no consistent steps are taken to bring about such uniformity and continuity as may be likely to tend to improvement either in the seed quality used in bulk, from year to year, or in crop quality.

These conditions result from (1) the failure of our educational campaigns to prevent the constant cropping of the soil to one crop or its close disease-infected cereal relations, and (2) the failure to hold varieties up to the standard of purity necessary to meet cropping and marketing needs. In the chief areas of cereal production, whether of wheat, oats, barley, or corn, constant cropping prevails as against constant processes of sanitary crop rotation. Particularly in wheat, barley, and oats cropping, the chief methods of production violate all the rules relative to standardized seeds more commonly than they are practiced. Here the large acreage producers and the elevators and process of marketing speedily undo all the ideas of crop sanitation and grain standardization. At least, they speedily bring the entire mass to an equilibrium of minimum yield and uniformity of admixtures. As the country elevator furnishes the chief supply of seed for the general cropping areas, an area of wheat does not represent one variety but several, and many types of infectious diseases which accumulate in seed and soil. In other words, we have no reliable basis of holding a crop to standardization and the work of each cereal crop improver and public educator on breeding dies with him. As to the truth of this one could cite many instances, as Wellman, Haynes, and Saunders.

These are strong assertions, but are easily maintained to the satisfaction of any person who knows field and market conditions. In the corn States corn culture is so overdone in large districts that the soil and seed is contaminated with fusarial types of fungi and other corn-root and seed-infecting organisms. The seed is generally reduced in vitality and the soil is so infected that in spite of the cultivation which is a necessity in that crop, good disease-free seed often fails to germinate properly in good fertile soil. This is but the story of the cotton crop, the flax crop, and the wheat crop over again.

THE WAY OUT.

Without attempting to argue the matter further, I propose in every cereal producing State a law authorizing field crop inspection, seed certification, seed standardization, and seed sales lists, all to be under supervision of an officer who holds his position, not thru local or political appointment, but because of his position as an investigator and educator associated with and directed thru the proper educational board. The law should be of such scope as to afford the basis for proper educational propaganda which would come as a necessary adjunct. It should carry funds sufficient for demonstrations and field work in the laying out of seed plots for standardization work. It should carry sufficient funds to allow a proper survey of every township, so that there may be a local supply of seeds which may be looked upon by the residents of that township as standard stuff of a given variety, and so inspected that it is reasonably free from the infectious diseases characteristic of the crop. The law should be equitably drawn and should be so worded as to allow of enforcement in the face of willful violation.

It is, I think, self-evident that the work of crop inspection, standardization, certification, and seed listing should be free for all citizens, consumers as well as growers. Further, those who do the certifying and listing should not be dependent for their positions on the number of bushels standardized, certified, and listed. This is perhaps the chief argument against the fee system. No citizen should be able to charge or think that the fee pays for the work.

It may be asked why the necessity? Simply because (1) the States and Nation are creating many varieties, perhaps valuable ones at great expense, only to be lost inside a few seasons of general cropping and marketing thru admixtures, disease contamination, and deterioration. If not lost, their qualities are quite camouflaged by the products obtained. (2) Seed inspection laws which only inspect

in the bag or bin in the place of seed sales after the seed is sold off the farm have failed and are failing to insure seed and crop improvement.

I do not mean by this that such inspection laws have not prevented the sale of much worthless seed. Under the present seed laws it has been possible to prevent the sale of large quantities of perfectly nonviable seeds and it has been possible to prevent the sale of seeds containing quantities of noxious weed seeds. It is not in this sense that I claim they have not succeeded, but rather that inspection after the crop is sold cannot improve the crop. Indeed, it may even deteriorate until there is really nothing worthy of the inspections and analysis wasted upon it. The seed merchant can only sell that which he buys and that which he buys cannot be better than what the farmers grow. If we are to improve that which is grown, it is evident that the inspection must be commenced earlier and with the cropping processes. One cannot improve that which is in the bin by inspecting it, he can only refuse to allow it to be sold until graded or cleaned. As, however, the admixtures are usually such that cleaning machinery cannot remove them, no amount of inspection will improve the breed and sanitary qualities of seed at this point. If the inspection starts on the farm and goes into operation with a view of aiding the grower to produce a better crop to be sold for seed for sowing purposes, or even for commercial purposes, then the money involved in the inspecting and in educating the public acts directly, and readily leads to an improved purebred seed plot. Within two or three crop generations it results in an entire farm crop of improved or pedigreed seed in sufficient quantity to fill wholesale seed houses or manufacturing warerooms. A sufficient number of such properly inspected crops will provide for the township and county needs and the process soon becomes infectious on adjacent farms. Thus standardization of varieties and proper recording of the growers may be established and thru authorized lists the grower of improved or pedigreed seed may be brought into authentic touch with those who wish to use the seed on the land. Seed inspection thus becomes at once a constructive process for improvement of seed quality and a means whereby records may be established and kept so that the breed may not be lost thru misrepresentation or ignorance.

Some may say that this can be done thru cooperative breeders' associations and by constantly renewed educational campaigns. That this is not possible, never has been done, and cannot be done because there is no tie to prevent such organizations running wild or dying

when the originators die, is self-evident and a historic fact. Such organizations usually die a natural death through the action of greedy members and false advertising propaganda. Who is there to check up the cooperative breeders' associations? Seed improvement must last thru the life of many men and for this there must be plans based on established law.

The one thing that can be said about our present haphazard method of breeding, seed recommendations, and educational propaganda is that all die out. Thru this system or utter lack of system there has accumulated an enormous number of synonyms, and numerous varieties mixed and jumbled into junk lots and misbranded kinds and the Nation quarrels as to how such cereals may possibly be graded for commercial purposes. These methods, with the craze for introduction of new kinds and the accompanying fallacies that varieties run out have so beset our agricultural public and plant-breeding workers that many able men are spending their time on the study of synonyms and the separation of varieties which, were the tasks accomplished, would be lost within three years should they cease their labors.

Even in potato culture, there are getting to be so many varieties and so much disease contamination in the chief potato districts that one can scarce load a car of a single variety reasonably fit for use as seed or even commercial marketing without hand selection and disinfection. What then must be the status with reference to wheat, oats, and barley?

The average person seldom sees anything smaller than potatoes and walnuts accurately, and this is literally true in regard to cereals. Some claim there is no necessity for such work because the national grain grades will eventually take care of this matter or should take care of it. Nothing can be farther from the fact. Nothing can be farther from possibility, for the national grades do not recognize variety. All hard spring wheat looks alike to the elevator and commercial man regardless of the variety. In milling and for feed purposes, in actual fact, it should make little difference. These should not concern themselves with variety further than the matter of kind. For commerce and manufacturing national grades are an essential necessity in order that all may be properly safeguarded. They should recognize qualities, as hard and soft, damp and dry, bright and moldy, etc., but they have little concern with variety. If they should, under present conditions, sufficient elevator bins could not be constructed to separate the varieties in any large cropping district.

In fact they do not. The fact that a sample of wheat is of No. 1 cereal quality, as No. 1 hard spring, does not at all insure its seed value. It may bear all the weed infection, disease infection, and types of wheat admixtures to which that particular region is heir, and the more the national grading system attempts to separate varieties in the grading system, the more certainly will their processes be damaging to agriculture.

The seed proposition must stand on its own merits and must be recognized as separate from the manufacturing proposition. If we care for crop improvement we cannot allow the seed standards in cereal cropping to be based upon national standards for flour and feed manufacturing. Nor can we as agronomists allow those in charge of the national grades to claim without rough challenge that they are protecting the varieties. As long as our farmers believe or are taught to believe that they have some protection from this source it will be possible for our wholesale seed houses to buy "No. 1 Northern Spring" or whatever the designation may be and sell it back to our farmers for seed as a basis for crop production.

FIELD SEED CROP INSPECTION.

The process of proper field crop inspection for seed production and seed standardization is a very simple one when properly authorized and put into operation. It can be done under any conscientious educational official administration of the State and can be continuous from one generation of officers to another without loss of the underlying methods and records. The natural home of such crop inspection would be associated with the work of the agricultural college and experiment station, where experts should exist or where it should be possible to develop experts in seed and crop standardization. The work can very naturally and properly be centered around the work of the pure seed office of the State. In its essentials it consists in the sending of competent inspectors to inspect the growing crops of those who claim to be growing seeds for sale for sowing purposes, or for special commercial enterprises. This inspection of the crop or stock may be done at any time before it is sold off the farm on which it is grown, but the proper time for such inspection is when the grain is in head, when even a novice in agronomic or botanical work need make no mistake as to variety, the percentage of admixture, and the possibility of disease infection, as scab, rust, ergot, smut, etc. A certificate should follow final inspection of the seed in the pure seed laboratory following harvest and thrashing. A State

list should be published showing the name of the grower, his address, and the variety and quantity of seed saved for sale as seed, and its authorization should be based upon the certificates as issued. Such State laws should specify various grades of improved grain, as "bulk seed of sufficient purity for use in special commercial processes or in general cropping," "improved seed," "pedigreed seed," etc.

Suffice it to say that this State listing necessitates official records of pedigrees and makes possible standardization and retention of varietal standards of quality. The whole process tends to form a proper educational basis for seed and crop improvement. Finally, the lists put any man who wishes to use the particular seed in touch with the man who is able to provide it. Thus good seed gets used on the land. The grower and the public are assured against having the work of proper tillage and proper crop rotation destroyed or set aside thru the use of false, unknown, or deteriorated varieties. The whole process tends to insure final crop standardization and is the necessary foundation for final establishment of marketing standards.

In North Dakota the process here outlined is not a matter of theory, but has been in operation on a part of the crops since 1909, and quite extensively in operation since 1911. Some hundreds of thousands of bushels of seed have been sold under the State list. We have made a beginning step on the right road looking toward cereal crop improvement. When a farmer or wholesale seed merchant once becomes imbued with the idea of standardized seed of a known quality, sold under certification, and if necessary under lead seal, he at once sees the necessity of following other processes of crop improvement, which follow as natural corollaries. Thus, one will not be apt to put such seed into lands which are weed infected, disease infected, or contaminated with other sorts of grains of the same kind, or junk the bulk product with inferior stuff on the commercial market. Improvements in lines of tillage and crop rotation must and will follow upon seed standardization as naturally as day follows sunrise. At present there is no real necessity of much improvement in tillage and crop rotation methods, for the seed used, very often, is of such quality from a sanitary and breeding standpoint as to thoroly offset any improvement that might be expected from better tillage methods and improved methods in soil sanitation.

AMERICAN HUSBANDRY, A MUCH OVERLOOKED PUBLICATION.[1]

LYMAN CARRIER.

This review is written to call attention to a 2-volume publication on American agriculture issued in London in 1775. The author does not give his name, but uses the pseudonym, "An American." Unfortunately, this publication, American Husbandry, has been generally overlooked by bibliographers of English and American literature. Allibone (1)[2] does not mention it, neither does Loudon (6) or McDonald (7), nor does it appear in the review of Colonial writings in the American Cyclopedia of Agriculture. Sabin (9) has an entry, "American Husbandry, see Arthur Young," that may refer to these books or that may have meant a chapter by that title in Young's "Annals of Agriculture," as Sabin's bibliography was never completed. Cushing (3) lists 38 different writers who used the pseudonym, "An American," but does not mention American Husbandry and none of the authors given is at all likely to have written this work. The Farmers' Magazine in 1801 refers to Bordley's (2) book as "the first American work upon practical husbandry which has come into our hands."

An extensive criticism of American Husbandry appeared in the London Monthly Review of January, 1776. Obadiah Rich (8) lists it. Flint (4) speaks of it as "An exceedingly interesting work," and Trimble (10) refers to it as "an indispensable source" of information on Colonial agriculture.

SCOPE OF THE WORK.

The author describes the soil, climate, and agricultural practices and products of the English colonies in America, beginning with Nova Scotia and Canada and following in geographical order with New England, New York, New Jersey, Pennsylvania, Maryland, Virginia, the Carolinas, Florida, and the West Indies. The agricultural possibilities of the Ohio and Mississippi valleys were empha-

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication March 18, 1919.

[2] References are to "Literature cited," page 211.

sized. In addition to this descriptive matter the objectionable farm practices are mentioned and remedies suggested. The staple commodities which each colony produced or was capable of producing are discussed from the standpoint of their value to Great Britain. Statements showing the capital necessary to establish a farm and the probable receipts and expenditures connected with its operation are given for most of the colonies. Direct comparisons are frequently made between the agricultural possibilities of America and England, with the advantages and disadvantages pertaining to each country.

PURPOSE OF THE WORK.

These books appear to have been written largely for the benefit of England and it was probably intended that they would be read in England more than in America. The author states "I particularly mean to explain everything in my power concerning the country management of America from its being so little known in England." This publication would have been very valuable to English emigrants to America, but a deeper political purpose appears back of their composition—to clear up the dense ignorance in regard to the colonies which prevailed in the English Government at that time. Had they been published earlier and given wide circulation they might have changed the histories of two great nations. At the time they appeared the Boston Tea Party and the battle of Lexington and Concord had put a stop to sober reasoning on both sides of the Atlantic.

LITERARY STYLE.

One of the most striking features of these books is the directness with which the author goes at his subject. There is a happy absence of the chapter of apologetic excuses for undertaking the great task of writing a book so customary in eighteenth century publications. Neither is there the misplaced theological discussion so common in the writings of the early preacher-agriculturists. They are as easy to read as any modern book on the subject, and are far superior to any other colonial agricultural writings. Another feature is the thoroness with which the different matters are discussed.

A fault which is quite noticeable is the unnecessary repetition of the same observations under different phases of the subject.

CHARACTER OF THE PUBLICATION.

The value of these books at the present time is due to the agricultural and not the political information which they contain. Com-

pared with the agricultural books published in the last half of the eighteenth century either in America or Great Britain, they stand far in advance of their time. They are also of much value from a historical point of view. The agriculture of the colonists, as described in "American Husbandry," differs considerably from that described in the agricultural histories and retrospects written in the past half century. In many of the latter, conditions have been colored to show a wonderful advancement in farming since the United States became a nation. As a matter of fact there has not been any great improvement except in the invention and wider use of farm machinery. The ordinary farm practices of his period did not meet the approval of the author of American Husbandry any more than present practices meet the standards of modern writers. The distinctly American practice of cropping a piece of land until it would not give a profitable yield and then turning it out for nature to restore the fertility while the same process was repeated on another area was strongly condemned. The closing chapters of the second volume, which deal with the possibilities of the colonies becoming independent and with the British colonial policy, must be classed among the most remarkable writings of pre-revolutionary times. They should be read by every student of colonial history.

Perhaps the nature of these books may best be shown by a few direct quotations.

> I need not observe here that in all countries one great principle of husbandry is the procuring and using as much dung and manure as possible: the farmers of New Jersey cannot raise hemp for exportation in large quantities for want of more manure; yet do they give into one practice which is very negligent; they leave the straw of most of the buckwheat they cultivate about their fields in heaps; they find their cattle will not eat it and so think there is no other use for it, but surely these men might reflect on the importance of litter, as well as food for cattle, in the consumption of their hay and other straw they might certainly use far more than they have or perhaps can have; but to possess it on their own farms without using it is unpardonable; nor is it a universal practice which keeps the whole country in countenance, for there are some planters who have better ideas, use all their straw carefully for litter and the advantage which these men reap from the practice ought surely to make the rest follow their example. There is no error in husbandry of worse consequence than not being sufficiently solicitous about manure; it is this error that makes the planters in New Jersey and our other colonies seem to have but one object which is the ploughing up fresh land. (Vol. I, p. 143.)

In discussing the agriculture of the New York colony he states:

> They should never exhaust their lands; and when they were only out of order they should give them what ought to be esteemed the most beneficial

fallow; that is, crops which while growing received great culture at the same time that they do not much exhaust the soil: such as all sorts of roots and pulse and every kind of leguminous plant with the various kinds of clovers.

A cropping system he recommended for one of the North Central Colonies was: 1, Indian corn; 2, potatoes; 3, Indian corn; 4, peas or beans; 5, barley; 6, clover; 7, wheat.

In this system no two exhausting crops come together, peas or beans and in general the plants which bear a leguminous flower being of a different nature from corn in this respect. (Vol. 1, p. 457.)

An experiment station was another of the things he advocated for the improvement of agriculture. He says:

It is impossible to know what the merit of the plants indigenous in these colonies is unless there is a plantation established at the public expense under the direction of a skilful botanist and one perfectly well acquainted with the practical as well as the theory of agriculture. In such a plantation improvement might be made in the culture of tobacco; vineyards might be planted and cultivated, both of the native vines and also of foreign ones. Experiments might be made on the culture of silk. All the native plants like those I have just mentioned which promised anything of utility might be brought into culture and trials made of their worth as materials for manufacture. Such a plantation well supported would be attended with some if not all those excellent consequences which flowed from the gardens of the Dutch East India Company at the Cape of Good Hope. (Vol. I, p. 275.)

Cotton we import from Turkey at the expense of above two hundred thousand pounds a year; this commodity agrees well with the soil and climate of Georgia, especially those of the back parts of the province; I am sensible that our West India islands would produce it but the land which is so occupied there would produce more valuable staples; there we want land, but on the continent is more land than we know what to do with. (Vol. II, p. 40.)

The cotton they cultivate here (eastern Louisiana) is a species of the white Siam. This East India and annual cotton has been found to be much whiter than what is cultivated in our colonies which is of the Turkey kind; both of them keep their color better in washing and are whiter than the perennial cotton that comes from the islands though this last is of a longer staple. (Vol. II, p. 84.)

THE AUTHOR.

It would appear from a study of American Husbandry that the author had lived both in England and America, and that he was loyal to Great Britain. He evidently had a scientific training, including a knowledge of botany, and was most familiar with the agriculture of Virginia and Maryland, but had also visited Pennsylvania and probably New England. A reasonable assumption would be that he had some connection with the British government as evidenced by the continual economic discussion of a political

nature, and one might reasonably suppose that these two books were not his first and only literary production.

The only man who seems to answer all of these requirements is Dr. John Mitchell, best known as a botanist and memorialized by *Mitchelli repens,* the pretty little partridge berry. As another paper bearing on the life of Doctor Mitchell has been prepared for publication elsewhere, only a brief account will be given here. Doctor Mitchell was born and educated in Great Britain and graduated an M.D. He came to America early in the eighteenth century and settled at Urbanna on the Rappahannock River in eastern Virginia. His first literary work seems to have been a small treatise on botany and zoology in 1738, followed by another in 1741 in which he proposed 30 genera of plants. These were published in 1748 by Doctor Trew of Nuremburg. Doctor Mitchell sailed for England in 1746 with an extensive botanical collection, but a Spanish privateer captured the ship and took his possessions. Mitchell reached England, but was compelled to give up his botanical work. He was made a fellow in the Royal Society in 1748 and two of his papers may be found in the Philosophical Transactions of that Society. About 1753 he was employed by the British Ministry to prepare a map of North America which was published in 1755. This map has been recognized as the most authentic of the colonial period and was the one used at the peace council at the close of the Revolutionary war. Accompanying this map Mitchell submitted a report which was published in 1757 entitled "The Contest in America between Great Britain and France, by An Impartial Hand." Another anonymous book which has generally been credited to Dr. Mitchell was entitled "The Present State of Great Britain in America," 1767.

In addition to the publications mentioned above this study has revealed two other anonymous publications which were undoubtedly the work of Doctor Mitchell. The first of these was "An Account of the English Discoveries and Settlements in America" in the revised edition of Harris' Voyages and Travels published in 1748 and which may be found also in Pinkerton's Voyages and Travels (1819). The second was entitled "A New and Complete History of America." This was issued in 1756 and consists of three volumes. The third volume ends abruptly in the middle of a word and the set was never completed. This is a very rare and little known publication.

As Doctor Mitchell died in 1768 or seven years previous to the publication of American Husbandry, the manuscript must have been edited by another. There is evidence of an attempt to disguise

Doctor Mitchell's part in its preparation. A careful comparison of these books with the other publications generally credited to Doctor Mitchell, together with those anonymous books mentioned above, leaves no reason for doubting that Doctor Mitchell was the author of American Husbandry and that the manuscript was in a fairly complete condition at the time of his death.

American Husbandry may be found in The Boston Athenaeum Library and the Boston Public Library, Boston Mass.; the Philadelphia Public Library and the Pennsylvania Historical Library, Philadelphia, Pa.; the Library of the Department of Agriculture and Library of Congress, Washington, D. C.; The Virginia State Library, Richmond, Va.; The Library of the Wisconsin Historical Society, Madison, Wis., and the Printed Book Department of the British Museum at Bloomsbury, England. It is probably to be found in some libraries other than the ones mentioned above.

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THE EXPERIMENTAL ERROR IN FIELD TRIALS.[1]

H. H. Love.

Under the title, "Studies concerning the elimination of experimental error in comparative crop tests," Professor Kiesselbach[2] points out the occurrence of experimental error in many kinds of crop tests. The bulletin is well prepared, contains much of value, and should be carefully studied by anyone engaged in comparative trials of any sort.

It is not the purpose here to review the bulletin in detail, but rather to point out certain cases which it seems might well be considered further. The first is competition that apparently occurs between different rows and the second the conclusion reached regarding the use of the probable error.

First, in regard to the competition between rows. The author compares the competition between thin and thick stand and obtains in this case a much smaller yield from the thin planting. The rate of planting is not given, unfortunately, so we cannot discuss this from that standpoint. Another point is not stated, that is, whether the series were so arranged that the rows ran from east to west or north to south. These points are omitted, altho the author (page 89) urges that the methods used by experimenters should be given. We have reason to believe that some of these rows at least extended east and west, so that competition would no doubt occur and perhaps be very marked in certain cases. As the direction of the rows is not made clear, it is well at this time to emphasize this point.

In certain experiments conducted at Ithaca, N. Y., where the rows run from north to south and data are available it is shown that there is little competition between varieties; in fact, there is so little between the ordinary varieties usually tested in any one locality that no correction would be necessary. Perhaps for other conditions the results would be different. In order to obviate any criticism of this method it might be well to follow the plan of arranging varieties

[1] Contribution from the Department of Plant Breeding, New York State College of Agriculture, Ithaca, N. Y. Received for publication February 26, 1919.

[2] Kiesselbach, T. A. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Expt. Sta. Research Bul. 13. 1918.

so that late sorts are grown together and the earlier ones together. In other words, the different sorts could be so arranged that they grade into one another as regards yield, earliness, and the like.

Now in regard to the use of the probable error the following is said for fear some persons might be misled and agree with the author in his conclusion. It is to be hoped that even greater use will be made of the probable error in interpreting results. A thoro study of its application will show its possibilities.

Professor Kiesselbach assumes that a field which has been sown to one variety of oats is uniform and makes 50 groups of 4 adjacent plats. He then states that

> If it is permissible to assume that one group of 4 duplicate plats is comparable with another group of 4 plats in the same field, then it would also seem permissible to assume that in the present instance, the mean yield for the entire 200 similarly treated oat plats should represent the correct yield or true value of any or all of the individual groups within the field. If this assumption be made with the adjacent duplicate plats (Table 32), the actual error of these group means exceeded their probable error approximately 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, and 15 times respectively in 9, 5, 7, 7, 8, 4, 4, 1, 2, 1, 1, and 1 groups.

In the first place his assumption is wrong for the field is not homogeneous as the following correlation will show. It is clear that the field is spotted and that the average yield of the 4 adjacent plats shows a gradual decrease from one side of the field to the other. The heterogeneous nature of the field is well shown if Harris' method of determining the heterogeneity is used, for $r = .206 \pm .046$. When such heterogeneity exists it is surprising that the deviation divided by the probable error as given in Column 11, Table 32, is not greater than it is and that 30 out of the 50 cases actually show that the deviation is not more than 3.8 times the probable error (meaning odds of about 30:1).

The author states that

> Among the 50 groups of adjacent plats, one group yielded 14.2 bushels less and another group 7.3 bushels more per acre than the 200-plat mean. These extremes represent an experimental error of 21.5 bushels since both should have yielded alike if the method of comparison were reliable.

What are we to conclude from this? If we compare the two groups, Nos. 30 and 50, with each other and consider their probable errors we see there is a difference of 21.5 ± 2.55 bushels. Does such a difference mean that the use of the probable error should be discontinued? Not at all—it means that the method of grouping 4

adjacent plats is at fault. It means that the average of 4 plats in one part of this field does not always represent the average of the entire field. Is there anything that points this out any more clearly than the probable error? Shall we refuse to use the probable error because it points out inaccuracies in our methods?

Now let us consider these data further. Instead of using the method for determining the probable error that the author used, which was to determine it from the standard deviation, some may prefer to use the more common method of determining the probable error by Bessel's or Peter's formula. The probable errors determined in this way will be slightly higher in value than the others and perhaps for a few individuals be just as reliable. When the probable errors are recalculated and the average yield of each four plats compared with the average yield of all the plats (with its probable error) the difference and the probable error of the difference can be obtained. It is this probable error that would then be used[8] to determine values for Column 11. When this is done we find the following:

Number of groups	0	1	2	3	4	5	6	7	8	9	10	11	15
Group means exceed probable error:													
When the author's method is used	9	5	7	7	8	4	4	1	2	0	1	1	1
When above suggested method is used	9	9	6	12	3	4	3	1	1	1	0	1	

This shows more of the groups falling in the lower classes so far as the ratio of deviation to the probable error is concerned.

Now when the grouping of these plats is made by combining systematically distributed plats the results are very different. There are only 3 groups whose ratio of deviation to probable error is greater than 3.8. If these were recalculated on the basis suggested above and the comparison made between the deviation and the probable error of the difference none of the plats would show a ratio greater than 3.8.

Now if we take the two groups showing the greatest plus and minus deviations in average yield we find that one yields 84.3 ± 1.45 and the other yields 72.0 ± 3.02. The difference between these two is 12.3 ± 3.35 which gives a ratio of 3.67:1. If the probable error is calculated on the other basis mentioned above, the probable error of the difference is 3.88 and the ratio only 3.17:1. Thus, we see that the systematic distribution of the plats gives results such that the average of any four plats considered in the light of the probable error

[8] The probable error of the difference should have been used to determine Column 11 in Tables 32 and 33.

will better represent the yield of the field. Now have we not here an excellent illustration of the value of the probable error for in the first method of grouping it shows that the method of grouping is not correct and in the second it shows that the method of grouping is such that any group fairly well represents the yield of the field as a whole?

The author points out that while the probable error is low, especially in the first method, the actual difference between groups is considerable. This is true in a number of cases and would be expected since the grouping is such that four low or four high yielding plats may be taken together. Their probable error might be low and yet the yield differ somewhat from the average yield of the entire field. We do not expect the probable error to be as large as the actual differences obtained in such grouping as that of grouping 4 adjacent plats in a field of such marked heterogeneity.

The author cites a case of the limitation of the probable error as follows:

> *Small Grain Row Tests.*—In Tables 1 to 7 were given the relative small grain yields of rate-of-planting or variety tests in alternating nursery rows. The plats were replicated 50 times and the probable error of the mean yields is indicated. The yields in these plats were subject to two sources of error, namely, soil variation and plat competition. Corresponding tests were also made in five-row plats relatively free from plat competition and subject primarily only to soil variations.
>
> In Table 1 (1913) the yields of the thick and thin planted wheat rows were, respectively, 389 ± 5.3 and 264 ± 3.8 grams. Altho the probable error for each yield is less than 2 percent the actual error of the relative yields due to competition is 24.4 percent. In 1914 the yields of the thick and thin planted wheat rows were respectively 327 ± 6.66 and 115 ± 3.6 grams. Altho the probable error for each yield is only 2 percent. the actual error of the relative yields, due to competition, is 56.8 percent.

Now this does not show the limitation of the probable error at all. The probable error of the 50 row plats and the 50 five-row plats is low in each case. This shows that the results obtained in each case are very reliable. In each case a different experiment has been performed. Competition causes a small yield for the thinly planted rows, which is apparently not so marked in the plats. It does not seem possible that any one would think that the probable errors of the two separate tests would be large enough to encompass the absolute differences due to the different methods. If such were the case the results with so large a probable error would be of no value whatsoever. Such an assumption regarding the probable error is wholly

unwarranted and erroneous. What the probable error shows is that (as stated above) the results are reliable and that in one case (rows) competition has a greater effect than in the other (plots). Such examples do not at all show the limitation of the probable error.

The author further states that

> Crop tests are subject to such a multitude of local environmental influences that errors in them cannot be regarded as occurring according to the formulas or rules of chance calculated from purely mechanical observations. The probable error calculation may apply, for example, to the chance drawing of black and white marbles from a bag at a given ratio to each other. But variations in crop yields are no such simple matter, and the probable error not only may have little significance, but may be misleading.

Now, if the deviations from the mean of all the plats are plotted or if the yields themselves are plotted, we obtain a very good frequency curve belonging to one of the well known types of frequency curves. In order to compare the difference between such occurrences as plot yields and other occurrences due to chance 8 pennies were tossed 200 times and the number of heads recorded. Here chance would surely operate fairly. The 200 tosses when grouped into a frequency curve of 9 classes gave no better distribution than when the 200 plot yields were grouped into a curve of 10 classes.

Does not the author assume the law of chance to operate when he combines results to obtain an average for any test? If the probable error is misleading when applied to such an average (because it is based on the law of chance) then is not the average misleading because it too assumes that the results fall some above, some below, the true value which for no better result is expressed in the average?

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the April JOURNAL was 525. Since copy for that number was sent to the printer, 11 new members have been added and 2 members have been reinstated, while news of the death of 1 member has been received. The names of the new and reinstated members, with such changes of address as have come to the notice of the editor or the secretary, are as follows:

NEW MEMBERS.

BOYD, JOHN B., State Normal School, Springfield, Mo.
CORMANY, CHAS. E., State College, N. Mex.
DAVIDSON, A. E., Warrensburg, Mo.
GRIFFEE, FRED, Kans. State Agr. College, Manhattan, Kans.
HOWAT, JOHN, Macon, Mo.
MCCLYMONDS, A. E., Kans. State Agr. College, Manhattan, Kans.
MITCHELL, JACOB N., 403 Exchange Bldg., Memphis, Tenn.
QUISENBERRY, KARL S., Kans. State Agr. College, Manhattan, Kans.
RAUT, ALFRED, Perryville, Mo.
SMITH, J. O. M., R. F. D. 14, Commerce, Ga.
WEEKS, CHAS. R., Hays Branch Station, Hays, Kans.

MEMBERS REINSTATED.

MACFARLANE, WALLACE, Agr. Expt. Sta., Honolulu, Hawaii.
TORGERSON, E. F., Dept. of Soils, Oregon Agr. Coll., Corvallis, Ore.

MEMBER DECEASED.

A. J. GALBRAITH.

CHANGES OF ADDRESS.

DILLMAN, A. C., Northern Great Plains Field Sta., Mandan, N. Dak.
HAGY, F. S., Belmond, Iowa.
LAUDE, H. H., Dept. Agronomy, College Station, Texas.
MARTIN, JOHN H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
SEARS, O. H., 123 Sheetz St., La Fayette, Ind.
TROUT, C. E., Jerseyville, Ill.
WALSTER, H. L., Dept. Agronomy, Agricultural College, N. Dak.

NOTES AND NEWS.

Brown Ayres, president of the University of Tennessee since 1904, died at Knoxville, January 28, 1919. Doctor Ayres was born in Memphis, May 25, 1856, and was a graduate of Stevens Institute of

Technology. Prévious to his election to the presidency of the University of Tennessee, he was a member of the faculty of Tulane University. He was prominent in educational organizations for many years, particularly in the Association of American Agricultural Colleges and Experiment Stations.

Samuel M. Bain, professor of botany in the University of Tennessee since 1901 and well known for his work on diseases of red clover and other crop plants, died January 30, 1919, at the age of 50 years.

J. B. Davidson, for the past four years professor of farm mechanics in the University of California, is to return on July 1 to Iowa State College as head of the department of agricultural engineering, the position he held before going to California.

Elmer O. Fippin, professor of soil technology in Cornell University, will become director of the agricultural bureau of the Lime Association on July 1. He has been connected with Cornell University since 1905.

F. S. Hagy is now instructor in vocational agriculture at Belmond, Iowa.

H. V. Harlan, agronomist in charge of barley investigations in the Federal Department of Agriculture, sailed May 2 for Europe, to assist in making crop surveys in Germany and Austria for the Grain Corporation.

W. D. Hurd, director of the extension service in the Massachusetts college since its establishment in 1909, has resigned to join the staff of the Soil Improvement Committee of the National Fertilizer Association on June 1. His headquarters will be in Chicago.

Willis E. Johnson, formerly president of the Northern Normal and Industrial School at Aberdeen, S. Dak., has been elected president of the South Dakota State College of Agriculture, succeeding E. C. Perisho, who is now engaged in educational work in Europe.

H. H. Laude, for the past several years superintendent of the Beaumont (Texas) substation, is now agronomist in charge of rice investigations for the Texas station, with headquarters at College Station.

R. D. Lewis has been appointed assistant in agronomy and J. S. Owens assistant in experimental agronomy in the Pennsylvania college and station.

John H. Martin, formerly superintendent of the Harney County Branch Station at Burns, Ore., is now assistant in western wheat investigations in the Federal Bureau of Plant Industry. He has been succeeded at Burns by Obil Shattuck.

Leroy Moomaw, formerly scientific assistant in forage crop inves-

tigations with the Federal Department of Agriculture and recently returned from military service in France, is now superintendent of the Dickinson (N. Dak.) substation.

Fred Rasmussen, professor of dairy husbandry in the Pennsylvania college, has been appointed Secretary of Agriculture for Pennsylvania and entered on his new duties January 21.

E. B. Reynolds, formerly associate professor of agronomy in the Texas college, is now superintendent of substation No. 3 at Angleton, Texas.

W. J. Smith has resigned as superintendent of county farms in Clermont and Hamilton counties, Ohio, and has been succeeded by H. W. Rogers, formerly foreman of the Madison County farm.

L. J. Stadler, assistant in farm crops in the Missouri college of agriculture, has resumed his work after an interval in military service.

H. C. Taylor, for many years professor of agricultural economics in the University of Wisconsin, has been appointed chief of the office of farm management of the Federal Department of Agriculture. F. W. Peck, formerly of the Minnesota station, will direct the cost accounting work in this office, which is scheduled to become a separate bureau at an early date.

John C. Thysell has resigned as superintendent of the Dickinson substation, Dickinson, N. Dak., and is now connected with the Northern Great Plains Field Station, Mandan, N. Dak.

E. F. Torgerson, formerly of the department of soil physics of the University of Illinois, is now assistant professor of soils in the Oregon college.

H. L. Walster, formerly of the department of soils of the University of Wisconsin, has been elected agronomist of the North Dakota station and has entered on his new work.

Louis Wermelskirchen, formerly assistant agronomist of the Texas station, is now teaching agriculture in the educational division of the United States Army at the Fort Sam Houston base hospital, San Antonio, Texas.

Roy O. Westley is agronomist of the Northwest substation and assistant professor of agronomy in the school of agriculture at Crookston, Minn.

L. M. Winsor, specialist in irrigation and drainage at the Utah college and station, has resigned to take up commercial irrigation work in Chile.

N. E. Winters, formerly superintendent of the Angleton (Texas) substation, is now engaged in extension work in agronomy at the North Carolina college.

C. M. Woodworth, of the University of Wisconsin, has been appointed to a position in the office of cereal investigations, United States Department of Agriculture, where he will have charge of special investigations of disease resistance in flax.

Meeting of the Ohio Section.

The annual meeting of the Ohio section of the American Society of Agronomy was held in Columbus, Ohio, during the week of January 27–31, in connection with the Farmers' Week program. The program of the week centered around the two topics of good seed and the importance of legumes in a permanent system of agriculture. The technical session was held on the afternoon of January 30, when an address was given by Director Burt L. Hartwell, of the Rhode Island station, on "The Effect of Crops on Those Which Follow as Influenced by Soil Treatments." The officers elected for the ensuing year are Wallace E. Hanger, president; F. A. Welton, vice-president; and Myron A. Bachtell, secretary-treasurer.

The Western Agronomic Conference.

The annual conference of agrononists of the eleven western States will be held at the University of California June 17, 18, and 19, 1919. The conference will convene on Tuesday, June 17, at 9 a.m., at the University Farm School, Davis. Wednesday, June 18, will be devoted to an automobile trip from Davis to Berkeley, passing thru several interesting farming sections. The session on Thursday, June 19, will be held at the University, Berkeley. The program will consist of round-table discussions, the principal topics selected for discussion being (1) problems of power in tillage and harvesting; (2) soil problems related to crop production; (3) farm crop diseases and treatments; (4) farm crop and seed production and utilization; and (5) problems of teaching and leadership. All those engaged in or interested in agronomic work in the Western States are urged to attend and to participate in the program. No formal papers will be presented, but all will be expected to take part in the discussion. Charts or other illustrative material will be welcomed, and lanterns can be provided for slides. All those who expect to attend are requested to inform Prof. John W. Gilmore, Division of Agronomy, University of California, Berkeley, Cal., and to state the topic or topics they will be prepared to discuss.

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THE WORK OF THE COMMITTEE ON SEED STOCKS.[1]

R. A. OAKLEY.

The conditions which gave rise to the slogan "Food will win the war" created a flood of interest in the seed stocks of the country immediately. America entered the conflict, and this prompted the Secretary of Agriculture to appoint a Committee on Seed Stocks whose duties, as he expressed them in brief, were to look after the supply of and demand for seeds.

Inquiries as to where seed could be purchased, where it could be purchased cheaply or obtained gratis, were reaching the Department daily in large numbers and one of the first steps taken by the newly created committee was to prepare partial lists of firms and individuals having seed for sale. This was to serve in satisfying the nervous as well as the legitimate inquirer. These lists, while far from complete and often belated in their appearance, served a very useful purpose. Coincident with the preparation of these lists, a piece of work of fundamental importance was undertaken by the committee. It consisted of taking an inventory of the country's stocks of seed. This disclosed much interesting information, especially since the committee had at its disposal the well organized machinery of the Bureau of Crop Estimates with its large corps of crop reporters, the machinery of the Extension Service, and the newly organized Seed Marketing Section of the Bureau of Markets, the inspection forces of the Bureau of Chemistry, and the crop

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Read before the eleventh annual meeting of the American Society of Agronomy at Baltimore, Maryland, January 7, 1919.

experts of the Bureau of Plant Industry. For the first time in its history it is believed that the Department got a real close-up view of the country's seed supply and learned at first hand what can happen in a commercial way when the country becomes apprehensive as to the adequacy of the supply.

After making a quick inventory of stocks it became evident to the committee that its most important immediate function was to disseminate information relative to the supply of and demand for seeds. It also became evident that to do this successfully some organization would be necessary in the States. Therefore, State committees on seed stocks were appointed to cooperate with the Department's committee, especially in the matter of disseminating information. The Federal Committee's function in this particular feature of its work was to act mainly as a clearing house for seed information. In this it is believed real service was rendered.

Early in its investigations, the committee discovered the need for a carefully planned program of crop production, for the reason that seed is a primary as well as an incidental crop, and its production has an important place in the nation's cropping system. We were at once confronted with the relative importance to the winning of the war of the cereals, the forage crops, and miscellaneous crops such as flax, sugar beets, etc. It was found necessary to draft a rough but conservative chart by which to steer a course, until a carefully prepared program of production could be formulated by the Department's special committee on production. The immediate need for a rational production program of some kind may be illustrated by our activities in the case of flax. We found the readily available supply of good seed for the spring of 1917 far from abundant to sow an acreage sufficient to produce seed for our crushing demands, estimated on the basis of our normal demands and our much reduced imports. If we needed the normal quantity of flax produced, it would be necessary to put on a campaign among grain dealers and oil mills with a view to cleaning up and saving seed for sowing a large acreage. Of course, the flax acreage does not come directly into keen competition with the spring wheat and other spring grain acreage, but there is an appreciable overlapping. Therefore we had to measure the relative need for these crops and put on our flax seed campaign accordingly.

The information on seeds assembled by our committee was helpful in the formation of the Department's 1917 production program, and in the carrying out of this program. In all the data that we

found available when our committee began its work, there were few upon which to base a satisfactory estimate of our actual seeding requirements for many of our important crops. We knew, of course, that our seed wheat and seed rye requirements for the acreage harvested, or to be harvested, in 1917 were approximately 72,000,000 bushels and 4,500,000 bushels respectively. We knew the approximate quantity of seed required for our acreage of all important cereal crops. In fact, we could estimate it closely for all our crops for which we had annually been making acreage estimates, but there were many crops for which we had no adequate estimate of acreage, and among these were many of our important forage crops and garden vegetables. The lack of knowledge of the quantity of seed required by our farmers and gardeners for planting our annual acreages of some of our important crops handicapped us in many ways, especially in shaping recommendations for seed production and in formulating policies that could be recommended with regard to exports and imports. We soon started some machinery in motion, however, and while our data even now are far from what is desired, I am glad to say we have made much progress.

Certain war emergency legislation which was enacted about the middle of the first year enabled us through the good offices of the Seed Reporting Service of the Bureau of Markets to get data from seedsmen and growers that assisted us materially in this connection. The Bureau of Crop Estimates put out some inquiries regarding acreage and seed needs that likewise produced very helpful results. In the first three months of our existence we had impressed upon us what we had already known, but probably had not appreciated to the fullest extent; that is, the fact that attention cannot be called to a shortage of seed with a view to conserving that particular kind without producing a marked tendency to increase the price and encourage speculation. We found it necessary therefore to exercise considerable discretion with regard to this point.

On August 10, 1917, the Food Production and the Food Control acts became effective. These greatly increased our work and enlarged its scope. The first new function which we had to perform under the emergency legislation developed with the fixing of the price of wheat. The Food Administration, which was already in existence awaiting legislative enactment, organized what is called the Grain Corporation as one of its subsidiary branches as soon as Congress provided authority for fixing the price of wheat. In a very short time after the adoption of the report of the "fair price" com-

mittee appointed by the President, the Grain Corporation formulated and promulgated regulations to maintain the fixed price level and control the wheat supply of the country. In these regulations was a provision against the storing of wheat in elevators and warehouses for a period longer than thirty days. It was soon found that the regulation, if strictly enforced, would interfere seriously with the storage of seed wheat, especially in the spring wheat areas and in the sections where winter wheat is sown before the crop of the same year is available, notably in the Judith Basin and other parts of the Northwest. The regulations did not go into effect in time to interfere with holding winter wheat for the 1917 sowing.

In a conference between members of the Grain Corporation and the Committee on Seed Stocks a plan was developed whereby seed wheat and also seed rye (rye also being under the control of the Grain Corporation), could be held until after the sowing season had passed. The plan was briefly this: A dealer wishing to hold wheat or rye for seed applied to his zone agent, who was the Grain Corporation's representative in his zone, for a license to store these seed grains. If he was in good standing with the Food Administration his application was approved and he was instructed to submit samples of the lots he desired to store to the laboratory of the Committee on Seed Stocks in his State or zone. These samples when submitted were examined and notification was sent to the dealer and also the zone agent as to their suitability for seed. In this way very close supervision was kept of the stocks of wheat and rye held for seed by grain dealers. To stimulate the holding of a sufficient quantity of seed, and in recognition of the cost of storing and handling it, the Grain Corporation allowed the dealers to charge not in excess of 15 percent above the Grain Corporation's price for the same grade of wheat at that point. The handling of the samples entailed considerable work which was done at four points: at Minneapolis, in a laboratory established especially for the Committee on Seed Stocks; and at Pullman, Wash., Moscow, Idaho, and Corvallis, Ore., in cooperation with the State agricultural colleges. Thousands of samples were examined and upward of a million bushels of wheat were approved and stored under this plan, in 1917–18. The Grain Corporation changed its plan of maintaining price levels for the crop of 1918, and the regulation limiting the storage of wheat to thirty days was abolished, therefore the committee has not been called upon to continue the work this year.

It was found necessary to exempt regular seedsmen from the regu-

lations regarding storage and from the 15 percent price differential for handling seed wheat. Generally speaking, seedsmen use more care with regard to the quality of seed wheat which they handle and many of them pay appreciably more than the milling price for it. Some of them sell it in small lots, and therefore greatly increase their cost of handling. Seedsmen were allowed to sell seed wheat and rye without regulations, but with the understanding that they would not profiteer, and it is believed that very little profiteering was done.

The Committee on Seed Stocks has nothing but praise for the work of the Grain Corporation insofar as it related to the handling of seed wheat. It rendered even a much greater service in another way than the one heretofore mentioned. Crop failures made stocks of good wheat scarce in parts of North Dakota and Montana, and the desire to increase the acreage of spring wheat in the spring of 1918, especially in the twilight margins of the spring wheat area, caused us to give no little consideration to the seed supply. To be brief, the Grain Corporation upon our recommendation stored wheat at points tributary to the areas where the crop of the preceding harvest was short, and also shipped seed wheat into the twilight areas where the tendency to sow indicated a demand for seed in excess of the supply. Approximately 500,000 bushels were provided for such sections by the Grain Corporation. A very appreciable and actual gain in the acreage, and subsequently in the harvest, was got by this action.

The activity of the committee which perhaps had the most direct bearing on the seed supply was undertaken in connection with the Food Production Act. Section three of this act contained the following provision:

> That whenever the Secretary of Agriculture shall find that there is or may be a special need in any restricted area for seeds suitable for the production of food or feed crops, . . . he is authorized to purchase, or contract with persons to grow such seeds, to store them, and to furnish them to farmers for cash, at cost, including the expense of packing and transportation.

For this work the sum of $2,500,000 was appropriated.

In the summer of 1917 severe damage resulted to crops from drouth, especially in parts of North Dakota, Montana, Kansas, Oklahoma, and Texas. By midsummer it became evident that many counties in these States would not produce seed enough to plant their normal acreages the following year. The situation became quite alarming and in view of the ever-sounding slogan, "Food will

win the war," more or less hysteria prevailed. Department and State officials made as careful surveys as possible of the seed situation in the counties where the drouth was most severe, and as a result of urgent recommendations by State and local agencies and public spirited individuals it was decided to use the authority above quoted to relieve the apparent emergency. In taking up this work, the committee had the following objects in mind: (1) to conserve seed that was badly needed in a locality from being used for food or feed, or in any way passing out of availability to the locality in which it was produced; (2) to insure an adequate supply of good seed for sections where an insufficient quantity was produced; (3) to assist financing agencies by making it possible for them to depend upon a definite supply of seed at nearly a fixed price; (4) to prevent speculation in seed and hold the price to a fair level.

After considering the needs and recommendations of the drouth-stricken areas, the Committee on Seed Stocks arranged for the purchase and sale of seed in Texas, Oklahoma, and Kansas, and in North Dakota and Montana. Seed of corn, cotton, the sorghums, and peanuts was purchased for Texas; sorghums for Oklahoma and Kansas; and barley, oats, and flax for North Dakota and Montana.

The severe drouth of the summer of 1917 was not the only factor that proved detrimental to the seed supply. On account of the very late season and early frosts and freezes, incalculable damage was done to the corn crop, and the supply of good viable seed produced in the northern part of the corn belt was far from sufficient for planting requirements. In the main, this was really the greatest emergency in our seed supply that existed during the period of the war. The committee recognized the seriousness of the situation early in the season and did what it could to call attention to the necessity of conducting seed-corn saving and testing campaigns. In this connection it may be said that the work of the State institutions, especially the extension services of the various States, was admirable and productive of excellent results. As time went on it appeared that something of a more definite nature than seed-corn saving and testing campaigns would be necessary if an adequate supply of good seed-corn was to be had. The committee was therefore urged to allot funds from the appropriation for the purchase and sale of seed conveyed in the Food Production Act, and in this connection aid was rendered especially in Ohio, Indiana, Michigan, Illinois, North Dakota, and Iowa. As a sufficient supply of local corn could not be had in all cases, the Committee on Seed Stocks, in cooperation

with the State officials, arranged for the importation of lots from other localities. In this connection it may be said that one of the largest experiments in seed-corn acclimatization was performed. On the advice and with the assistance of the State authorities seed-corn from Pennsylvania and Delaware was shipped to Ohio and Michigan, and from New Jersey to Indiana. It was impossible to get seed-corn of varieties nearly adapted to North Dakota conditions except in the New England States, and several cars were shipped to North Dakota from Rhode Island and Connecticut. In connection with this experiment it may be said that the results proved highly satisfactory. Possibly the long favorable season had much to do with the outcome, but at any rate the reports received to date are very favorable.

As the planting season approached, the committee was urgently requested to use the funds at its disposal for the purpose of providing a reserve supply of seed-corn for late planting and replanting. Some of the financial agencies that were assisting in providing corn for first planting could not use their funds for the purpose of providing a reserve for ieplanting. The committee, after carefully considering the situation, concluded that the importance of insuring a large acreage of corn was sufficient to warrant the risk that might be taken in buying seed for a replanting reserve. The seed purchased by the Department for first planting was all sold to farmers, but a rather large percentage of that purchased for reserve was not used since the weather during the planting season was so favorable thruout the entire corn belt that the replanting requirements were very far below normal.

In its emergency purchase and sale of seed, the Committee sold in all enough for planting approximately 1,200,000 acres. It did not sell all the seed purchased. In this connection it was handicapped by the wording of the law which made it necessary to sell at cost, and therefore allowed no margin to take care of declining prices. In the drouth-stricken area of the Southwest, the drouth continued so late in the spring of 1918 that the demand for seed was very greatly reduced, and this, together with the fact that the supply of seed especially of the sorghums was much greater than had originally been estimated, caused a decided break in the sorghum seed market, and speculators offered their stocks much below cost.

There were several points clearly brought out in connection with the emergency purchase and sale of seeds. Probably the most important of all was that price goes far toward overcoming seed shortages. It is really remarkable how much seed will come on to the

market as the result of very attractive prices. The estimates of the requirements made by State officials were naturally in favor of their own interests, a fact which is to their credit. Taking everything into consideration, however, it is believed that the emergency purchase and sale of seed resulted in much good, not only in providing good seed in many localities that had practically none, but in stabilizing prices.

A writer in a well-known "snappy story" agricultural paper, after commenting on the tenacity with which the committee held to the seed information which it had, stated that he did not know whether the emergency purchase and sale of seeds resulted in a financial loss to the Federal Government, but he did think that the committee deserved credit for doing something.

The committee was called upon to cooperate with the War Trade Board, an emergency organization, especially with regard to giving advice that would help in shaping intelligent export and import policies. During the war, the War Trade Board virtually controlled the exports and imports of this country through a system of licensing. Seedsmen were required to obtain licenses before they were permitted to export seeds, except in a few cases where the exports were to Canada and Cuba. The committee found it necessary to recommend the laying of temporary embargoes in a few cases, and to advise the restricting of exportation, especially to northern neutral countries who were asking in some cases for seed far in excess of their normal net importations. At the present time there is a temporary embargo on the exportation of red clover seed, except to Canada, and as red clover seed is now on the conservation list, licenses are required before lots can be exported to that country. Exports to Canada are being carefully watched, and only the normal requirements will be allowed exportation. It appears from data that are available, that the supply of red clover seed now in this country is insufficient for our sowing demands. We are gathering data on this point, however, and propose to make a definite recommendation to the War Trade Board by January 15, 1919, which will enable them to decide whether to retain the embargo, or to lift it wholly, or in part. England is anxious to get red clover seed, as are also some of the northern neutral countries. There appears to be a tendency toward the accumulation of supplies of seed in parts of Europe to supply the market in Russia, Germany, and Austria when it opens up. Manifestly we could not well spare clover seed badly needed here for such a purpose, but I think this country is willing to share seed with England to the extent of at least part of her needs.

The Committee on Seed Stocks has endeavored to follow a policy that would aid the legitimate seed business of the country, and has in many cases submitted recommendations to the various war boards with this point in view. Almost immediately after the declaration of war by this country, the American Seed Trade Association and the Wholesale Grass Seed Dealers' Association organized war service committees. These committees have held briefs for the seedsmen on various occasions, and have served a very useful purpose in presenting matters that were important alike to the seedsmen and the country. The Committee on Seed Stocks has had very cordial cooperation with these committees and wishes to take this opportunity to express its thanks for the willingness with which information and help has been offered in the war emergency.

In looking back over the work of the committee we realize probably more clearly than we did before that the seed production and distribution machinery of the country was very well adjusted, and that it needed only a little help and possibly control here and there to keep it in good working order. At the present time the seed supply of the country is in excellent condition, so far as its abundance is concerned. The very high price that obtained, especially for garden seeds, resulted in a greatly increased acreage of these seeds and consequently a very large harvest. We have now large surpluses of most of our important vegetable seeds, and it is not known to what extent the demand abroad will use these surpluses.

The personnel of the committee is as follows: W. A. Wheeler, Chief of the Seed Marketing Section, Bureau of Markets; L. M. Estabrook, Chief of the Bureau of Crop Estimates; C. R. Ball and C. W. Warburton, Office of Cereal Investigations, Bureau of Plant Industry; W. A. Stuart, Office of Horticultural and Pomological Investigations, Bureau of Plant Industry; C. H. Kyle, Office of Corn Investigations, Bureau of Plant Industry; J. E. W. Tracy, Office of Seed Distribution, Bureau of Plant Industry; R. A. Oakley, Chairman, Office of Seed Distribution, Bureau of Plant Industry; and A. J. Pieters, Secretary, Office of Forage Crop Investigations, Bureau of Plant Industry.

We wish to take this opportunity to thank the State institutions and individuals for their very hearty cooperation. It was indeed a pleasure to work with the State committees and with the officials of the colleges and experiment stations.

THE RELATION OF CERTAIN EAR CHARACTERS TO YIELD IN CORN.[1]

H. HOWARD BIGGAR.[2]

Considerable study has been made by experimental workers to ascertain whether any of the various ear characters of corn can be used as a guide in selecting ears for high yield.

The data in this paper deal with the relation between certain ear characters and yield, in five varieties of corn grown at five different points. The characters here considered, in their relation to yield, are length of ear, weight of ear, number of rows of kernels, and the shelling percentage. The tests from which the data were derived were ear-to-row tests, conducted with a view to varietal improvement.

REVIEW OF PREVIOUS INVESTIGATIONS.

Montgomery (6)[3] states that his results indicate the yielding value of a long, smooth type of ear. He also states that a medium depth of kernel is preferable to deep or shallow kernels.

Olson, Bull and Hayes (7) state that close selection for high scoring ears is of no practical value in increasing the yield of corn. They report the following coefficients obtained in a correlation study of ear characters and yield with Minnesota No. 13.

Character.	Coefficient of correlation.	
Length	+.098	±.040
Weight	+.047	±.044
Circumference	—.052	±.041
Shelling percentage	+.157	±.043

Williams and Welton (9) state that in ten years of experiments which they conducted the yield secured from long ears was 1.39 bushels per acre more than the yield secured from short ears. In

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication April 5, 1919.

[2] Credit is due the following men of the Office of Corn Investigations who have made measurements of ears and conducted field work with the varieties discussed in this paper: Messrs. E. B. Brown, G. J. Burt, H. S. Garrison, J. M. Hammerly, C. P. Hartley, C. E. Trout, J. G. Willier.

[3] Reference is to "Literature cited," p. 234.

nine years of experiments, tapering ears outyielded cylindrical ears by 1.65 bushels per acre. Six years' experiments with ears having an average shelling percentage of 88.16 as compared with ears averaging 76.38 percent showed a slight increase in yield for the ears with the lower shelling percentage.

Love (3) found that there was some relation between length and weight compared with yield, but that such characters as number of rows, average weight of kernels, and ratio of tip to butt circumferences do not have any very marked effect upon yield.

Love and Wentz (4), working with Funk Yellow Dent, found that circumference of ear was correlated with yield, but that the correlation was never consistently high. Their weight correlations were all positive but small. The correlations of yields and shelling percentages were all negative, and in field tests ears with a high shelling percentage averaged 0.692 pound per stalk, while ears of low shelling percentage averaged 0.753 pound per stalk.

Cunningham (1) arranged the ears of several varieties in groups of long, medium and short ears. There was no correlation between length of ear and yield. He found that slender ears were more productive than ears of large circumference, and that there was no relation between shelling percentage and yield.

McCall and Wheeler (5) found that correlations of ear characters and yield were not consistent, and that neither length, weight, or density were correlated with yield.

Hutcheson and Wolfe (2) state that they found a relation between length and weight and yield, but that such characters as number of rows and percentage of grain showed little relation to yield.

VARIETIES USED IN THIS STUDY.

The five varieties studied for correlation were: Selection 77, a large white dent grown at Piketon, Ohio; Selection 120, a large white dent grown at Round Hill, Va.; Selection 119, a large white dent grown at Occoquan, Va.; Selection 133, a small yellow dent grown at Oconomowoc, Wis.; and Selection 204, a medium sized dent grown at Hawarden, Iowa. Four years' results are given for Selection 77, and three years for each of the other varieties. The relative differences in the ear characters of the five varieties are shown in Table 1, in which the averages of the characters for the various years of the test are given:

TABLE 1.—*Average weight of ears, length of ears, number of rows, and shelling percentage of five varieties of corn studied.*

Variety.	Weight of ears.	Length of ears.	No. of rows.	Shelling percentage.
	Grams.	*Inches.*		*Percent.*
Selection 77	324	8.4	14.6	86.2
Selection 120	347	8.8	12.7	85.6
Selection 119	363	8.9	16.8	83.5
Selection 133	218	7.1	15.3	81.9
Selection 204	257	8.0	17.3	83.4

The table shows that Selection 119 and Selection 120 have the heaviest ears, and that these same varieties have also the longest ears. Selection 204 and Selection 119 have ears with the greatest number of rows. Selection 77 and Selection 120 have ears with the highest shelling percentages.

Table 2 gives the correlation coefficients of yield compared with weight, length, number of rows of kernels, and shelling percentage, for each variety in the various years.

TABLE 2.—*Coefficients of correlation between yield and weight of ears, length of ears, number of rows, and shelling percentages.*

Variety and year.	Weight.	Length.	Number of rows.	Shelling percentage.
Selection 77:				
1914	+ .085 ± .073	+ .177 ± .071	+ .046 ± .073	− .309 ± .066
1915	+ .261 ± .065	+ .067 ± .071	− .028 ± .070	− .028 ± .070
1916	+ .188 ± .061	+ .120 ± .064	+ .025 ± .063	− .105 ± .063
1917	+ .064 ± .072	+ .133 ± .072	− .146 ± .071	+ .001 ± .073
Selection 120:				
1915	+ .200 ± .090	+ .175 ± .091	− .226 ± .089	− .148 ± .091
1916	+ .076 ± .083	+ .001 ± .083	+ .062 ± .082	+ .276 ± .077
1917	+ .200 ± .091	+ .279 ± .090	− .025 ± .095	− .117 ± .093
Selection 119:				
1915	+ .296 ± .074	+ .231 ± .079	+ .063 ± .081	+ .067 ± .082
1916	+ .131 ± .083	+ .354 ± .075	− .147 ± .082	− .063 ± .084
1917	+ .565 ± .061	+ .330 ± .081	− .131 ± .088	+ .155 ± .088
Selection 133:				
1912	+ .070 ± .079	+ .063 ± .080	− .007 ± .079	− .370 ± .076
1913	+ .334 ± .072	+ .381 ± .071	+ .061 ± .081	− .017 ± .081
1914	+ .130 ± .070	+ .301 ± .066	+ .015 ± .071	+ .166 ± .069
Selection 204:				
1916	+ .145 ± .093	+ .082 ± .096	− .024 ± .095	− .368 ± .082
1917	− .074 ± .062	+ .068 ± .064	− .040 ± .063	+ .042 ± .063
1918	+ .097 ± .075	+ .276 ± .071	+ .055 ± .075	− .263 ± .070

RESULTS.

All of the weight correlations are positive, with the exception of that for Selection 204 in 1917. These positive correlations range from + .07 for Selection 133 in 1912 to + .565 for Selection 119 in 1917. In three cases the probable error is greater than the coefficient.

In the case of Selection 119 in 1917, the coefficient is nine times the probable error.

In every case there is a positive correlation between length and yield, ranging from +.001 to +.381. In four cases the probable error is greater than the coefficient. The relation of length to yield will be taken up more fully in Table 3, in which the long and the short ears for each variety in each year are compared as to yield. The ears of each variety were divided into approximate halves representing long and short ears. The table gives the average length of each set of ears, the increase of longs over shorts in percentage, and the increase in bushels per acre, allowing 50 bushels per acre for the minimum yield.

TABLE 3.—*Data on correlation between length of ears and yield.*

Variety and year.	Average length.		Correlation coefficients (all plus).	Increase of longs over shorts.	
	Long ears.	Short ears.		Percent.	Bushels.[a]
	Inches.	*Inches.*			
Selection 77:					
1914......	8.7	7.6	.177	1.8	.90
1915......	9.5	8.4	.067	1.3	.65
1916......	8.8	7.8	.120	− .5	.25
1917......	9.0	7.7	.133	1.2	.60
Selection 120:					
1915......	8.7	7.7	.175	1.6	.80
1916......	9.4	8.4	.001	− 2.1	−1.05
1917......	9.7	8.7	.279	3.3	1.65
Selection 119:					
1915......	8.8	7.6	.231	4.0	2.00
1916......	9.8	8.9	.354	7.1	3.55
1917......	9.9	8.4	.330	16.7	8.35
Selection 133:					
1912......	7.3	6.6	.063	4.3	2.15
1913......	7.5	6.7	.381	10.2	5.10
1914......	7.8	6.8	.301	6.2	3.10
Selection 204:					
1916......	8.4	7.4	.082	2.5	1.20
1917......	8.7	7.9	.068	1.0	.50
1918......	8.3	7.1	.276	5.0	2.50

[a] Assuming a minimum yield of 50 bushels per acre.

The character of number of rows compared with yield shows nine negative correlations and seven positive ones. In twelve comparisons out of sixteen, the probable error is larger than the correlation coefficient.

In the case of shelling percentage, there are ten negative correlations and six positive ones, indicating a tendency toward higher yields for ears with low shelling percentage.

CONCLUSIONS.

There seems to be no special relation between number of rows and yield, or between shelling percentage and yield. The characters of length and weight of ears show positive correlations with yield, but they are not consistently large. The character of length seems to be somewhat significant, at least for some of the varieties.

The results would, on the whole, indicate that there is no well marked basis for using ear characters to indicate yield possibilities.

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EXPERIMENTAL ERROR IN FIELD TRIALS.[1]

T. A. KIESSELBACH.

In a recent issue of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY, Doctor H. H. Love[2] questions certain conclusions of mine[3] on (1) competition between adjacent test rows as a source of experimental error and (2) limitation in the use of the probable error calculation. I am indebted to Doctor Love for his criticism and am gratified that the majority of my conclusions apparently meet with his approval. An explanation of my position may clear up some points on which we appear to differ.

COMPETITION BETWEEN SINGLE ROW TEST PLATS.

Shade as a factor ~~is~~ in row competition between somewhat unlike varieties, selections, or rates of planting was not entirely overlooked in the bulletin in question. On page 15 of Nebraska Research Bulletin 13 is given an illustration of spring wheat growing adjacent to winter wheat as an extreme example of competition, and on page 14, line 22, it is stated that the spring wheat was planted to the south of the winter wheat. For the sake of brevity it was left to the reader to conclude that the matter of shading could in this case not be the limiting factor in competition. It is, however, further stated that in this case the "complete failure of the first row of spring wheat may be accounted for by the shortage of both moisture and available plant food material, due to the more rapid and luxuriant growth of the adjacent winter wheat. While this is an extreme example of competition between adjacent rows, it illustrates a principle commonly applying in crop yield tests." Some of our competition studies were conducted with the rows running north and south and others east and west. While we have never made a comparative study of the

[1] Contribution from the Department of Agronomy, Nebraska Agricultural Experiment Station, Lincoln, Nebr. Received for publication June 2, 1919. This paper is a reply to a criticism by Doctor H. H. Love of Cornell University of a bulletin by Professor Kiesselbach. Proof of Doctor Love's criticism was sent to Professor Kiesselbach, but his reply was not received until the issue containing Love's article was in press.

[2] Love, H. H. The experimental error in field trials. *In* Jour. Amer. Soc. Agron. 11: 212-216. 1919.

[3] Kiesselbach, T. A. Studies concerning the elimination of experimental error in field trials. Nebr. Agr. Expt. Sta. Research Bul. 13. 1918.

exact effect of the direction of the rows we certainly have had striking competition, no matter what the direction of the rows. In his criticism, Doctor Love appears to assume that shade is the only factor in plat competition, overlooking the other more important elements.

Competition studies reported were not confined to rate-of-planting tests, but include comparisons between varieties and types as well. The same general principles are brought out in each case.

The rate-of-planting tests with small grain extended over a period of two years, 1913 and 1914, and the results are reported in the bulletin in question on pages 15–18. Probably Doctor Love has overlooked my statement in the bulletin on pages 18 and 19 regarding the exact number of plants in the thick and thin rates of seeding. It is true that the rate of planting was not given, but in both table and discussion the exact number of plants in 10 feet of row was stated, which eliminates the uncertain factor of imperfect germination. Furthermore, I have given the exact number of stools, which throws additional light on the actual amount of vegetation in each case. Perhaps it was an oversight on my part in not connecting Table 3 more closely with Tables 1 and 2 by some such means as a footnote instead of the simple statement preceding Table 3. It was assumed that the careful reader would not fail to see the connection. Table 3 gives the figures only for 1914, while the statement should have been made that planting rates for the two years were as nearly duplicates as possible. In the case of the competition rate-of-planting tests with corn the exact rate was stated for every trial for every year. In order to further clarify the matter of plat competition the paper published elsewhere in this issue[4] has been prepared.

Doctor Love's suggestion that the likelihood of error resulting from row competition would be reduced by grouping varieties of rather similar growth habit together, would without doubt reduce such error. However, in the first year of many experiments in which unfamiliar crops are tried for the first time, such grouping might not be very dependable. Furthermore, it appears that varieties fairly similar in growth habit may differ for some reason in relative competitive quality.

PROBABLE ERROR.

A statement of my position regarding the use of the probable error would doubtless not be out of place in this connection.

[4] Kiesselbach, T. A. Plat competition as a source of error in crop tests. *In* Jour. Amer. Soc. Agron., v. 11, no. 6, p. 242–247. 1919.

1. The probable error has a legitimate use.

2. It indicates the precision among replicates, but a small probable error in no way proves that those replicates may not all vary similarly due to a methodic or systematic error running thruout the series, or to certain accidental groupings. A small probable error indicates the absence of serious accidental errors or variations within a series of replicates. This is especially true if reasonably large numbers are averaged. Its dependability is greatly reduced in case of low frequencies. While a small probable error may indicate such precision, it does not necessarily indicate reliability, dependability, or accuracy as to the inherent intrinsic comparative values sought.

3. Thru misapplication the probable error may act to cover or support data that is worthless or actually misleading because of errors that it does not and cannot reveal.

4. There are two general classes of experimental errors, accidental and systematic. In many experiments there may be an intermingling of both sorts. Accidental errors are such as distinctly local and rather abrupt soil irregularities within the confines of an experimental field, and irregularities in stand caused by rodents, cutworms, etc. Among the systematic variations or errors may be included plat competition, where distinct types or planting rates are grown in very close proximity as in adjacent rows, and serious soil limitation in pot fertilizer experiments, either thru size of pot or thru rate of planting.

A systematic variation may under certain conditions be reflected in the probable error and in other cases it may not. This depends upon the constancy of the error. A constant or methodic error running through a series is not adequately shown in the probable error. This is illustrated in the reference to thickness of planting in pots on pages 73 and 74 of the bulletin. If one crop is planted thruout the experiment at a normal rate and another crop in comparison is planted unconsciously at an excessive rate, tho all pots practically agree and the probable error is small, the results are not dependable.

In many pot fertilizer experiments, the crop has been unconsciously subjected to a serious soil limitation, as is illustrated in Tables 39, 40, and 45 of Nebraska Research Bulletin 13. Working out the probable error for pots in which the soil is seriously limited, either thru size of pot or thru rate of planting, would in no way disclose such soil limitation as invalidating the results from the standpoint of the values sought.

If a series of plats are duplicated in the same relative order in a

sloping field the variety which falls at the lower end of the series each time is likely to be favored thruout by more favorable moisture and fertility conditions. If one is aware of such a soil variation the planting order of duplicate series may be so rearranged as to overcome the systematic variation in large part and thereby more nearly restrict the tests to accidental variations. The actual error would thereby likely be diminished without a corresponding decrease and with possibly even an increase in the size of the probable error. Systematic variation of this sort in crop tests may doubtless be overcome in part by check plat corrections.

5. In general, of itself, probable error indicates little apart from other complete description of the experiment showing replication and proper extent of the work. Its use is to be encouraged to indicate precision only, when the experiment has been planned and carried on in a manner agronomically sound. Hiding meager or poorly founded data behind a low probable error, which may be done unless the methods are adequately stated, would be unscientific.

Concerning Doctor Love's criticism of my discussion on probable error, I am obliged to feel that, in the main, Doctor Love and I are agreed but that in my attempt at brevity I failed to make myself clearly understood.

In the first place let us consider the criticism of my analysis of the use of the probable error in single row comparative yield tests. What is the correct application of this conclusion? For example, as a method study two distinct comparative yield tests of two different rates of planting were made under rather similar conditions for Turkey winter wheat. One test was made with two planting rates in adjacent rows, subject to plat competition as all single row test plats are to a greater or less extent. A corresponding test was made in larger blocks containing 5 rows of a kind and naturally far more free from plat competition. In part of the tests practically all effect of plat competition in the blocks was eliminated by discarding the border rows. In both experiments, whether tested in rows or in blocks, the probable error was relatively small—about 2 percent. Had only the single row comparative test been made without the block test as a check upon it, and by attaching the usual significance to the probable error, one would have concluded that the results in the row tests were very reliable as indicating the intrinsic relative productivity of the two rates. Now that is exactly what is likely to happen with the extensively used single row comparative yield test plats. Nebraska as well as Cornell and many other stations have

repeatedly used the single row test plat, especially in grain breeding work, rather unconscious of the magnitude of the experimental error often resulting from plat competition. What I had in mind in the bulletin was to bring out the fact that one might work out the probable errors for the comparative yields obtained in single test rows, concluding from small probable errors that the results were reliable and dependable as to inherent productivity, whereas the hidden, unrecognized error of competition might have resulted in very faulty data and erroneous conclusions.

At the Nebraska station, we have not used the single row plat during the past five years except in method studies. The Minnesota station has also recently concluded that competition is likely to invalidate results from single rows. Of course, during the first year in certain crop improvement work, before a sufficient supply of seed is available, it may be necessary to use single rows, but one cannot place much confidence in these preliminary results.

In Volume 2 of the Proceedings of the American Society of Agronomy,[5] a plan is outlined for testing, in single rows, light and heavy kernels in cereals. The experiments call for rather striking differences in planting rates. Anyone conducting such a test might work out the probable error for the ten replications and conclude from the small probable error which is almost certain to result that the data are reliable. In fact, however, the yields would be apt to be subject to striking plat competition as I have described and the results be not only unreliable but very misleading. I am calling attention to this article only for the sake of illustrating the fact that our entire experimental procedure is a matter of evolution of methods and many unconscious errors have been committed which the competition studies reported in my bulletin indicate.

One purpose in presenting the data for 200 thirtieth-acre oat plats arranged into 50 groups of 4 adjacent plats was to show that an apparently uniform field may be very heterogeneous, and that it would be a great fallacy to plant, as has occasionally been done, a number of adjacent duplicate plats and attach much significance to the mean results. In this particular case such a procedure would seem absurd since the heterogeniety of the field is made so evident by virtue of the entire field having been planted to a single variety of oats. However, had this been an actual test of 50 varieties in 4 adjacent duplicate plats, the absurdity would not have been so evi-

[5] Montgomery, E. G. Methods of testing the seed value of light and heavy kernels in cereals. *In* Proc. Amer. Soc. Agron., 2 (1910): 59–69. 1911.

dent. I state in the discussion criticised by Doctor Love that the experiment "shows that a uniform appearing field may be so heterogeneous in soil conditions that its mean yield cannot be regarded as correctly representing the true value of its various parts." Attaching significance to probable error calculations of this sort would be a fallacy. It would be a misapplication rather than a shortcoming of probable error.

With reference to Doctor Love's criticism on page 213, let us assume that instead of these 50 groups of 4 adjacent plats all planted to one variety, we have fifty distinct varieties. In such a case the probable error calculation for the extreme variation of 21.5 ± 2.55 bushels would not be evidence that the grouping of 4 adjacent plats is at fault, but if used at all it would probably be used to indicate an actual intrinsic difference in productivity. The probable error used in a varietal test such as this would not throw light upon the inaccuracies of the methods, the opinions of some investigators notwithstanding. I may state that I have also called attention in the bulletin to the greater reliability of systematically replicated plats than of adjacent duplicate plats. I have further stated that "an application of the probable error to these systematically distributed plats would seem fairly reasonable."

In my discussion of the probable error in the bulletin, I undertook rather to point out cases where the probable error would not apply and would in fact lead to erroneous conclusions in certain cases, than to eulogize the probable error and set forth its possibilities. Our experimental work along this line was more by way of elimination.

We feel very confident that care must be exercised in applying the probable error interpretation to experiments greatly subject to systematic errors in order that unwarranted confidence in the results be not thereby engendered. Furthermore, its use in connection with means of very low frequency is of very doubtful value in crop tests. It was not my intention to condemn the use of the probable error altogether, but rather to set forth certain cases of misapplication.

I wish to attempt to clarify one further example given in the bulletin which I fear I may not have made quite clear. This occurs in the bulletin under the heading, "Water requirements of corn and wheat." It seems self evident in the case I have given that the probable error interpretation will not apply in the water requirements of wheat planted at the normal field rate and corn planted at 6 times the normal rate. However, if such a test were conducted, as has been done many times by various investigators, quite unawares

of the discrepancy in relative planting rates, the absurdity would not be so evident and perhaps not at all apparent. There are a number of instances where this identical oversight in planting rate in past experiments has occurred and in the published results, small probable errors are given as evidence of the reliability of the experiment.

I am aware that there are several formulas for working out the probable error. I had thought it of little importance which I used in this purely theoretical discussion of principles. Somewhat different results are obtained in the size of the probable error, according to the formula used, but this would not seem materially to affect the general conclusions regarding the basic principles in the use of the probable error. I merely selected the formula given by Davenport (Principles of Breeding, 1907 ed., p. 440) for the reason that other parts of my discussion were also based upon his work.

I realize that a critical search into the actual significance of the probable error as applied to crop experiments is almost pioneer work. In this pioneer work one is apt to offer suggestions and interpretations which justify criticism. The ultimate result will, however, be wholesome if it provokes further inquiry looking toward a correct solution. Certainly the suppression of such inquiry would be undesirable.

Dr. Love asks the question, "Shall we refuse to use the probable error because it points out inaccuracies in our methods?" May I in turn ask Doctor Love if we shall recommend without qualifications the indiscriminate use of the probable error when without question it acts in many cases to give credence to very faulty results? Shall we leave unmodified the very common understanding that by "giving the probable error along with any result, the reader may know what degree of confidence is to be placed in the results"?

PLAT COMPETITION AS A SOURCE OF ERROR IN CROP TESTS.[1]

T. A. KIESSELBACH.

INTRODUCTION.

That a rather keen competition for soil moisture and nutrients is likely to exist between plants differing in growth habit when grown in close proximity is a well recognized principle in ecology. Investigations conducted at the Nebraska Agricultural Experiment Station indicate that this element of competition is a greater source of experimental error in crop tests than is commonly appreciated. This source of error occurs most extensively in small grain nursery row tests and in 1-row or 2-row corn test plats, in which two sorts are grown side by side. Its most exaggerated case is, perhaps, the testing within a single hill of several corn types differing markedly in growth characteristics.

Errors resulting from such plat competition appear to be fully as pronounced in many cases as are the errors resulting from soil and other environmental variations, remedies for which have long been sought in the use of check plats and in replication. This effect of competition is a hidden error which cannot be corrected and should be avoided by supplying proper experimental conditions.

The general conclusion relative to comparative yield tests to be drawn from these investigations is that any crop being tested should be surrounded by a crop of its own kind in order to avoid the effect of competition with a dissimilar crop, for moisture, nutrients, and possibly light.

The principles brought out in these tests concerning plat competition should be applicable to any yield test in which dissimilar crops are being compared. This may be accomplished for all practical purposes by substituting plats containing three or more rows for single row plats and then discarding from the yield test the outer rows which are subject to competition with the adjoining plats. In case of wide field plats, discarding the outer rows is not so important since the percentage error for the entire plat caused by competition would be much lower. The degree of error resulting from such

[1] Contribution from the Department of Agronomy, Nebraska Agricultural Experiment Station, Lincoln, Nebr. Received for publication June 2, 1919.

competition will depend primarily upon the extent to which the crops being tested differ in their vegetative characteristics. The competition will also vary in different seasons.

The following investigations were made for the purpose of determining the extent to which plat competition is a factor in crop yield tests. In these experiments the relative yields of the crops compared in well replicated blocks containing 5 rows for small grain and 3 rows for corn were regarded as the true relative values for the particular crops. Any difference in their relative yields when grown in single adjacent rows may be ascribed to plat competition. In the more recent tests the outside rows of blocks have been discarded and the true relative yields, practically free from competition, based upon the remaining rows. The small grain plats have been replicated 50 times and the corn plats 8 or more times in these tests in order to eliminate the accidental mechanical and physical errors due to variation in soil, exposure, stand, etc.

SMALL GRAIN RATE-OF-PLANTING TESTS.

During two years, Turkey winter wheat was sown in both alternating single row nursery plats and in alternating 5-row nursery plats at two distinct planting rates, 2 and 5 pecks per acre. The rows were 16 feet long and 10 inches apart. In 1913 the thin rate yielded 90

TABLE 1.—*Relative yields of two rates of seeding Turkey wheat and Kherson oats when compared in alternating rows and in alternating 5-row plats.*

TURKEY WHEAT.

Year and rate of seeding.	Average yield of 50 plants.			
	Alternating single rows.		Alternating 5-row blocks.[a]	
	Grams.	*Percent.*	*Grams.*	*Percent.*
1913:				
Thick rate (5 pk.)	389	100	394	100
Thin rate (2 pk.)	264	68	355	90
1914:				
Thick rate (5 pk.)	327	100	251	100
Thin rate (2 pk.)	115	35	203	81
KHERSON OATS.				
1913:				
Thick rate (8 pk.)	233	100	222	100
Thin rate (4 pk.)	148	64	178	80
1914:				
Thick rate (8 pk.)	220	100	202	100
Thin rate (4 pk.)	148	67	207	102

[a] Yields based on 3 inner rows of 5-row plats in 1914.

percent as much as the thick rate in blocks, and only 68 percent as much in competing single row plats. In 1914 the thin rate yielded 81 percent as much as the thick rate in blocks and only 35 percent as much in competing rows. The thin rate is seen to have been at a decided disadvantage when grown in rows adjacent to the thick rate.

In a similar test in 1913 with Kherson oats, the thin rate (4 pecks per acre) yielded 80 percent as much as the thick rate (8 pecks per acre) in blocks, and only 64 percent as much in competing single row plats. In 1914 the thin rate yielded 2 percent more than the thick rate when compared in 5-row blocks, while in competing single rows it yielded 33 percent less.

SMALL GRAIN VARIETAL TESTS.

Two varieties of winter wheat, Turkey and Big Frame, were compared during 1913 and 1914 in both alternating single-row nursery plats and in alternating 5-row plats, sown at the rate of 5 pecks per acre. In 1913 the Big Frame wheat yielded 3 percent less than the Turkey when grown in 5-row blocks, whereas in competing single rows it yielded 7 percent more. In 1914, the Big Frame again yielded 3 percent less than the Turkey in 5-row blocks, while in single competing rows it yielded 15 percent less. In a similar test between Turkey and Nebraska No. 28 wheat both varieties yielded relatively the same whether in rows or blocks in 1913, the Nebraska No. 28 yielding 7 percent more in each case. However, in 1914, the Nebraska No. 28 yielded 15 percent less than the Turkey in the blocks, and 37 percent less in the competing rows.

The relative competitive qualities of two varieties or selections may reverse in different seasons according to climatic conditions, as seen in both the above wheat varietal tests and the following oat varietal tests.

Kherson and Burt oats sown at the rate of 8 pecks per acre were compared in alternating rows and blocks during two years. In 1913, the Burt yielded 12 percent more than the Kherson when grown in 5-row plats and 30 percent more in alternating single rows. In 1914, the Burt yielded 1 percent more than the Kherson in blocks and 39 percent more in competing rows.

Kherson and Swedish Select oats were compared likewise in rows and blocks, at the rate of 8 pecks per acre. In 1913, the Swedish Select yielded 23 percent less in blocks and 18 percent less in competing rows than the Kherson. The following year, Swedish Select yielded 7 percent less than Kherson in blocks and 11 percent less in competing rows.

The data on these tests are given in Table 2.

TABLE 2.—*Relative yields of two small grain varieties when compared in alternating rows and in alternating 5-row plats.*

WHEAT.

Year and variety.	Average yield of 50 plats.			
	Alternating single rows.		Alternating 5-row blocks.[a]	
	Grams.	*Percent.*	*Grams.*	*Percent.*
1913:				
Turkey	325	100	408	100
Big Frame	347	107	397	97
1914:				
Turkey	342	100	320	100
Big Frame	290	85	310	97
1913:				
Turkey	365	100	396	100
Nebr. No. 28	390	107	423	107
1914:				
Turkey	369	100	334	100
Nebr. No. 28	232	63	285	85

OATS.

Year and variety.	Alternating single rows, Grams.	Percent.	Alternating 5-row blocks, Grams.	Percent.
1913:				
Kherson	201	100	209	100
Burt	261	130	234	112
1914:				
Kherson	152	100	204	100
Burt	211	139	207	101
1913:				
Kherson	192	100	191	100
Swedish Select	157	82	147	77
1914:				
Kherson	205	100	219	100
Swedish Select	182	89	204	93

[a] Yields based on 3 inner rows of 5-row plats in 1914.

CORN RATE-OF-PLANTING TESTS.

Nebraska White Prize corn was grown for 3 years at the rates of 2 and 4 plants per hill in both alternating rows and alternating 3-row plats. In the latter case the two outer rows were discarded. The corn was checked in rows 72 hills long, 42 inches apart. It was planted thick and later thinned to the desired rate. The yields were based upon 59 hills in each row containing and surrounded by the desired stand.

In 1914, the 2-plant rate yielded 16 percent more than the 4-plant rate in blocks and 18 percent less in competing rows. In 1915, the 2-plant rate yielded 31 percent less than the 4-plant rate in blocks,

and 37 percent less in competing rows. In 1916, the 2-plant rate yielded 7 percent less than the 4-plant rate in adjacent blocks and 22 percent less in competing rows.

The data are given in detail in Table 3.

TABLE 3.—*Relative yields of Nebraska White Prize corn from two rates of planting when compared in alternating rows and in alternating 3-row plats.*

Year and rate of planting.	Yield per acre.[a]			
	Alternating single rows.		Alternating 3-row blocks.[b]	
	Bushels.	*Percent.*	*Bushels.*	*Percent.*
1914:				
Four plants per hill.......	43.8	100	38.4	100
Two plants per hill.......	35.6	82	44.3	116
1915:				
Four plants per hill.......	101.7	100	90.0	100
Two plants per hill.......	64.2	63	62.0	69
1916:				
Four plants per hill.......	52.7	100	51.8	100
Two plants per hill.......	41.5	78	48.6	93

[a] Yields are averages from 8 plats, except that 15 alternating single rows and 9 alternating 3-row blocks were averaged in 1914.

[b] Yield from the center row of the 3-row block.

CORN VARIETAL TESTS.

Plats similar to those just described in the rate-of-planting tests were used in the corn varietal tests. In addition to being compared in alternating rows and blocks, two varieties of corn were also grown within the same hill and their yields compared.

When compared in blocks, rows, and within the same hill, Pride of the North yielded respectively 85 percent, 68 percent and 47 percent as much as did Hogue Yellow Dent corn in 1912. A similar test in 1913 was not harvested because of an almost complete corn failure, due to drouth. In 1914, the yield of Pride of the North was 53 percent of that of Hogue Yellow Dent in blocks, 38 percent in rows, and 28 percent in the same hill.

A selfed strain of Hogue Yellow Dent corn which had been greatly reduced in vigor was compared in a similar test in 1916 with an F_1 hybrid of two selfed strains of the same variety. In blocks the inbred corn yielded 37 percent, in competing rows 31 percent, and within the same hill 21 percent as much as the crossbred corn.

The data on these tests are given in Table 4.

TABLE 4.—*Relative yields of two corn varieties when compared in alternating rows, in alternating 3-row plats, and within the same hill.*

Year and variety.	Yield per acre.					
	Alternating 3-row blocks.[a]		Alternating single rows.[b]		Planted in same hill.[c]	
	Bushels.	Percent.	Bushels.	Percent.	Bushels.	Percent
1913:						
Hogue Yellow Dent	38.4	100	50.8	100	26.2	100
Pride of the North	32.9	85	33.7	66	12.2	47
1914:						
Hogue Yellow Dent	63.1	100	77.8	100	36.9	100
Pride of the North	33.7	53	29.2	38	10.6	28
1915:						
Hogue Yellow Dent	65.8	100	68.3	100	30.4	100
University No. 3	64.7	98	61.0	90	30.0	99
1916:						
F_1 hybrid of Hogue Yellow Dent inbred strains	76.2	100	90.5	100	54.0	100
Inbred Hogue Yellow Dent	28.1	37	28.0	31	11.3	21

[a] Yields based on center row of 3-row plats in 1914 and 1916. Yields are averages from 10 plats except in 1916, when only 9 plats were averaged. There were 3 plants per hill except in 1916, when 4 plants per hill were grown.

[b] Yields are averages from 20 plats except in 1916, when only 6 plats were averaged. There were 3 plants per hill except in 1916, when 4 plants per hill were grown.

[c] One plant of each variety in the hill except in 1916, when two plants of each were grown in each hill. Yields are averages from 1,000 hills except in 1916, when yields of 300 hills were averaged.

CLIMATIC ADAPTATIONS OF THE WHITE TEPARY BEAN.[1]

G. W. HENDRY.

INTRODUCTION.

The singularly perfect adaptation of the Tepary bean to arid climates was first commented upon by the Arizona Agricultural Experiment Station in 1912.[2] Since that time this bean has become an important field crop thruout the arid southwest, and has extended its range well into the interior valleys of California, where no less than 17,000 acres were devoted to its production in 1918.

During five years of field experimentation with this new crop at the several California substations, it has become increasingly evident

[1] Contribution from the Division of Agronomy, College of Agriculture, University of California, Berkeley, Cal. Received for publication March 14, 1919.

[2] Freeman, G. F. Southwestern beans and teparies. Ariz. Agr. Expt. Sta. Bul. 68. 1912.

that the Tepary bean has certain specific climatic requirements in the absence of which it does not thrive. This paper treats of the relation of the white Tepary bean (*Phaseolus acutifolius* A. Gray var. *latifolius* Freeman) to its climatic environment and especially of its peculiar reaction to the cool coast climates of central and of northern California.

RELATION OF CLIMATE TO VEGETATIVE DEVELOPMENT.

Normal Tepary plants grown in the semiarid interior districts of California acquire an open trailing habit and may, under favorable circumstances, attain a total length of 50 or more inches; but those grown in the cooler coast climates north of Point Conception develop abnormally. The plants assume a dwarfed, compact, bush habit, are devoid of runners, and rarely exceed 20 inches in length. The leaflets become smaller, thicker, and develop a crumpled texture. The pods are produced sparingly, become shorter and broader, and contain fewer seeds. The seeds take on a characteristic grayish white color, absorb sufficient atmospheric moisture to become slightly enlarged, and frequently germinate feebly in the pods prior to the ripening of the vines. The life period is prolonged indeterminately, and the foliage continues green until destroyed by frost. Typical plants grown in the two environments are shown in Plate 8.

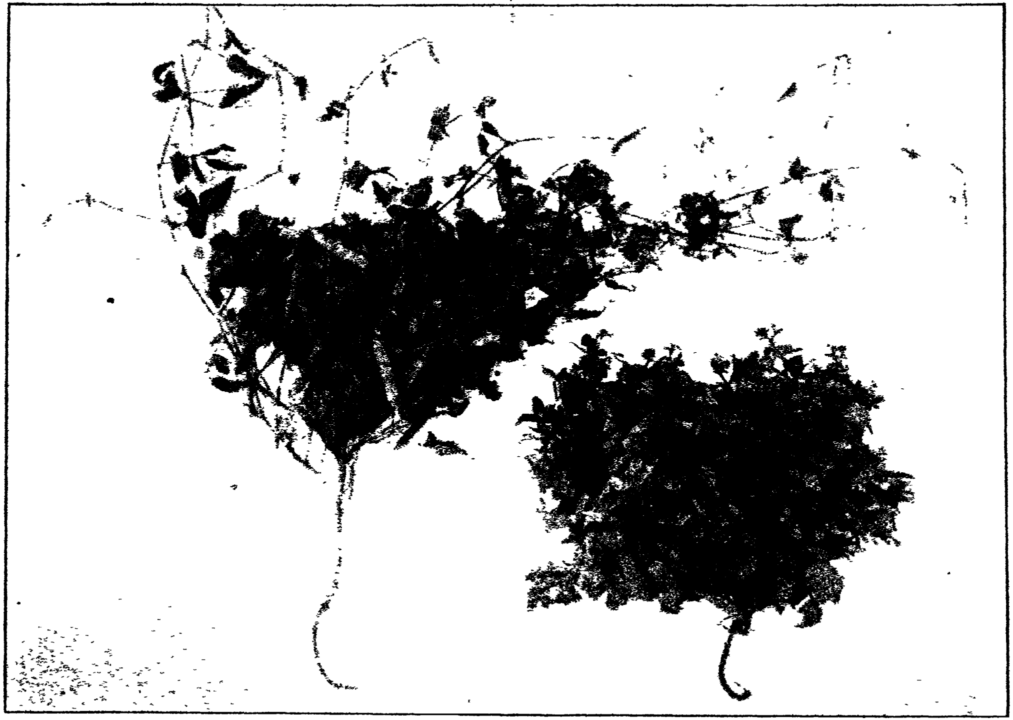
COMPARATIVE YIELDS FOR SEMIARID INTERIOR CALIFORNIA.

Varietal trials with beans including Teparies have been conducted at three University of California substations situated at Davis, Fresno, and Riverside, representative of the interior portions of northern, central and southern California respectively. The figures in Table 1 are compiled from the data obtained and show clearly the greater prolificacy of the Tepary at these places.

TABLE 1.—*Comparative yields of White Tepary and Pink beans at semiarid interior stations.*

Locality.	Number of years.	Average yield per acre in pounds.	
		White Tepary.	Pink.
Davis	3	815	470
Fresno	2	3,005	322[a]
Riverside	1	3,159	683

[a] One year only.



White Tepary bean plants, illustrating the effects of climatic environment upon vegetative development. The larger, normally developed plant (left) was grown in the semiarid climate at Davis and is 54 days old. The smaller, dwarfed plant (right) was grown in the cooler subhumid coast climate at Berkeley, and was immatire when photographed 129 days from planting.

These data, decisive as they are, merely confirm a wide experience, all of which testifies to the excellence of the Tepary as an arid climate crop. The Pink bean, *Phaseolus vulgaris,* here employed as a check, is the best known and most extensively cultivated variety in the southwest, where it has few equals within the species in point of yield. Under very trying conditions of heat and aridity, however, such as prevail during the summer months in the localities of these experiments, the Pink is greatly reduced in prolificacy and compares unfavorably with the more drouth-tolerant Tepary.

COMPARATIVE YIELDS FOR SUBHUMID COASTAL CALIFORNIA.

While evincing high merit with respect to yield in the interior districts, the Tepary has made a decidedly unfavorable impression in the coast regions, as is shown by the yield data (one year only) in Table 2.

TABLE 2.—*Comparative yields of White Tepary and Pink beans at subhumid coast stations.*

Locality.	Yield per acre in pounds. White Tepary.	Pink.
Berkeley	1,244	1,512
Santa Cruz	0	562
Smith River	155	683

At Santa Cruz, representing the south central coast region, at Berkeley, representing the central coast region, and at Smith River, near the Oregon line, representing the extreme northern coast region, the yield relationship with the Pink has been reversed. Moreover, in these localities the Tepary has been exceeded in yield by numerous other *Phaseolus vulgaris* varieties. The yield of 1,244 pounds per acre obtained at Berkeley is relatively high, but was secured under artificial conditions, in that the crop was cured and thrashed by hand, indoors. Had usual field methods been employed, the crop could not have been saved from the rains and the yield would have been virtually nothing.

These tests, together with numerous other observations in the field, have clearly shown the climatic limitations of the Tepary, and have proved it to be imperfectly adapted to the cool coast regions of central and of northern California.

THE RELATIONSHIP OF CLIMATE AND PLANTING DATE TO THE PRE-BLOSSOMING PERIOD.

The interval from planting to the complete opening of the first blossoms, here designated as the pre-blossoming period, has been

found to be a function of climate, and to vary with the locality and atmospheric temperatures subsequent to planting. It has been longest in cool climates and has been increased or diminished as the planting date has caused its occurrence during cool or warm weather. Observations upon these relationships follow in Table 3.

TABLE 3.—*The relation of locality and planting date to the pre-blossoming period of Tepary beans.*

Berkeley.		Davis.	
Planting date.	Pre-blossoming period in days.	Planting date.	Pre-blossoming period in days.
May 1	80	April 13	91
May 17	78	May 30	51
July 2	77	July 5	42
Average	78	Average	61

At Berkeley the average pre-blossoming period was 78 days, while the corresponding average for the warmer climate of Davis was 61 days. The fact that the early planting at Davis required 91 days to blossom, a longer period than for any other planting either at Berkeley or Davis, is due to the circumstance that this planting was made eighteen days earlier than the earliest Berkeley planting, and was followed by a period during which exceptionally low temperatures prevailed. In the three months immediately following this planting the minimum temperatures were 31°, 37° and 41° F., while the corresponding temperatures for the months following the first planting at Berkeley were 41°, 44°, and 51° F. On the other hand, the mean temperatures for the summer months immediately following the second and third plantings at Davis averaged from 10° to 15° F. above the corresponding temperatures at Berkeley, resulting in short pre-blossoming periods of 51 and 42 days respectively, compared with 78 and 77 days for the cooler climate of Berkeley.

TABLE 4.—*Mean temperatures for Berkeley and Davis, Cal., by months from April to December 1917*[a].

Month.	Mean temperature (°F.).		Month.	Mean temperature (°F.).	
	Berkeley.	Davis.		Berkeley.	Davis.
April	55.6	57.6	September	66.1	71.6
May	55.4	60.2	October	63.0	66.8
June	62.0	73.2	November	57.6	53.7
July	63.2	78.7	December	54.8	48.0
August	60.2	75.0			

[a] Beals, E. A. *In* Ann. Climat. Rpt., Cal. Sect. 1918.

THE RELATION OF CLIMATE AND PLANTING DATE TO THE BLOSSOMING PERIOD.

It has also been ascertained that the interval from the complete opening of the first blossom to the falling of the last blossom (here referred to as the blossoming period) is also a function of climate, that it is longer in cool climates than in warm climates, and that it is either increased or diminished in any locality as the planting date causes it to occur during cool or warm weather. Some observations upon these relationships appear in Table 5.

TABLE 5.—*The relation of locality and planting date to the blossoming period.*

Berkeley.		Davis.	
Planting date.	Blossoming period in days.	Planting date.	Blossoming period in days.
May 1	57	April 13	44
May 17	35	May 30	35
July 2	74	July 5	35
Average	55	Average	38

The average blossoming period for the three Berkeley plantings was 55 days, while the corresponding average for the warmer climate of Davis was 38 days. The effect of planting date upon the blossoming period and the correlation between the blossoming period and mean temperatures are here well illustrated. The blossoming period for the second planting at Berkeley was only 35 days compared to 57 days and 74 days, respectively, for the first and third plantings, and since the blossoming period of this second planting occurred during the highest prevailing temperatures (Table 4), its brevity is in harmony with the relationship previously noted.

The second and third Davis plantings caused the blossoming periods to occur during the intense heat of July and August (Table 4), in consequence of which very short blossoming periods of 35 days each resulted. The blossoming period of the first Davis planting, on the other hand, occurred during cooler weather, in consequence of which it was lengthened to 44 days, and doubtless it would have been still longer had not the long pre-blossoming period of 91 days caused it to occur so late in the season.

THE RELATION OF CLIMATE AND PLANTING DATE TO THE LIFE PERIOD.

The life period is here regarded as the time elapsing from the planting of the seed to the complete ripening of the plants. Since its duration is in part determined by both the pre-blossoming and the

blossoming periods, it varies as they do and is governed by the same influences. Some observations upon its relation to climatic variations are shown in Table 6.

TABLE 6.—*The relation of locality and planting date to the life period.*

Berkeley.		Davis.	
Planting date.	Life period in days.	Planting date.	Life period in days.
May 1	157	April 13	148
May 17	135	May 30	96
July 2	166[a] +	July 5	92
Average	153 +	Average	112

[a] Killed by frost in December prior to maturity.

The average life period for Berkeley was 153 + days, while for Davis it was 112 days, again illustrating the relationship between temperature and period of development. The third Berkeley planting resulted in the development of the plants during cool autumn weather (Table 4), in consequence of which these plants had shown no indications of ripening previous to their destruction by frost, 166 days subsequent to planting. It was in this planting that the abnormal vegetative development previously described was most apparent.

The first Davis planting matured in 148 days, the second in 96 days, and the third in 92 days, and as the mean temperatures for these periods vary inversely as the corresponding durations (Table 4), the observations are in harmony with the relationships as previously stated.

SUMMARY.

Tepary beans grown in the cool climates of the central and northern California coast districts develop abnormally.

The White Tepary is more prolific than varieties of *Phaseolus vulgaris* in the semiarid interior districts of California.

The White Tepary is less prolific than varieties of *Phaseolus vulgaris* in the subhumid coast districts of central and northern California.

The pre-blossoming period, the blossoming period, and the life period are each functions of climate. They are longer in cool climates than in warm climates, and they are either increased or diminished as the planting date causes them to occur during cool or warm weather.

WHAT IS THE VALUE OF THE USUAL LABORATORY WORK GIVEN IN GENERAL SOILS COURSES?[1]

P. E. KARRAKER.

In connection with a study of the soils courses outlined in the catalogs of a number of the State agricultural colleges, attention has been directed to the nature and value of the usual laboratory work given as a part of the first or general soils courses. There is no question as to the value of this work to the small number of men who will later specialize in investigational or teaching work in soils or very closely related lines. It must be kept in mind, however, that these are required courses in most colleges, and even where they are not, are taken by practically all men finishing undergraduate work. There is a question, it would seem, as to the value of this work compared with other courses which might be taken, to the large number of men who will not thus later specialize.

Only a very small part of the laboratory work in soils is that in which the average student is gaining a knowledge and something of the art of doing operations which he will be using in post-graduation activity. In this respect the soils work differs from the laboratory work in such courses as stock-judging, farm mechanics, and the first courses in dairy husbandry and in horticulture, in that here the student is going thru operations which will be common to his post-graduation activity and with which previous to his class work he was more or less unfamiliar; and it is in this relation to post-graduation activity that the value of these courses must be mainly found. Laboratory work in soils to be of a similar nature in this respect would have to include such practices as the plowing and preparation of land, the application of fertilizers, etc. It is obvious why work of this nature is not given. It is either not adaptable to laboratory conditions, or else constitutes such a common part of farm practice that students are familiar with it before entering college.

From the standpoint of mental discipline, the usual laboratory work in connection with soils courses takes at least equal rank with that given in connection with other courses in agriculture, but this qualification alone does not constitute a justification for the work. From this standpoint alone not only this work but most of the courses

[1] Contribution from the Department of Agronomy, University of Kentucky, Lexington, Ky. Received for publication April 18, 1919.

in technical agriculture could not be justified when compared with certain more exact fundamental courses in liberal arts and natural science.

Let us consider more in detail the laboratory work usually given in connection with the introductory or general course in soil physics. What is the value to the average student, for instance, of determining that air-dry soils contain a certain amount of hygroscopic moisture, that these soils suffer a certain loss on ignition, that soil samples from the field contain so much capillary moisture, that the apparent and real specific gravities of stock soils are so much? Does the value, *i. e.*, a justifiable value, come from the operations involved in securing these results? It would not seem so, but if it is here could it not better be secured in the more accurately controlled laboratory work in courses such as those in chemistry and physics? Or is the value to be found in the more firm fixing in the mind of the student of the facts in question than results from the study of the printed page alone? Again it would not seem so. Is it not open to question whether either the nature of the facts themselves or the gain in vividness from this manner of their presentation justifies the work?

Further, the results from a number of the practices usually given are apt to be misleading to the student. The usual determination in the laboratory of the capacity of soils for capillary water gives considerably higher results than obtain under field conditions. Results from the practices with air and percolation movement of water thru soil unless restricted to work with various grades of sand, are dependent more on the fineness of grinding of the stock soils than on their texture. Clay soils which resist fine grinding usually show greater freedom both of air and water movement than the coarse-textured soils. There is a tendency for the practice showing capillary movement of water up into air-dry soils to give to students the idea that the soil with greatest capillary movement is the most desirable from the moisture standpoint. The important thing under field conditions, however, is moisture retention and not moisture movement and one very important factor making for moisture retention, the content of organic matter, works against extent of capillary movement in the practice in the laboratory. A marked example of a misleading laboratory practice is that showing the effect of mulches in saving moisture when but a short distance above a water table. In all these practices it is necessary for the instructor to explain very clearly that the conditions under which the results are secured are not comparable to field conditions and therefore the results themselves are of but limited application.

The practices referred to in the preceding two paragraphs do not include all the work usually given and some of the work is not thus open to question. Unfortunately, however, the great important processes concerned in the making of the earth's surface a suitable place for the growth of crops, such as the change of rock into soil, the building up of the soil organic matter and nitrogen content, the production of good structural conditions, movement and control of water and air under field conditions, and the way crops feed either can not be reproduced accurately or else can not be reproduced at all by the student in the laboratory, especially the student in the first course.

An additional and a different reason for the need of attention to the laboratory work usually given in general soil physics courses is that already some of this work has been and in the future an increasing part of this work will have been done by the students in agricultural courses in secondary schools previous to entering universities.

The laboratory work in the usual first or general course in soil fertility, even more than that in soil physics, finds its declared value mainly in the analytical results secured. A large part of such work is the determination of nitrogen and phosphorus and less often of potassium in farm products, manures, fertilizers, and soils. Practices may also be included showing nitrification, fixation of bases, etc., but such practices are not on the whole well adapted to laboratory work in these courses.

The average student does the laboratory work in soil fertility with interest, but again the question arises as to the particular way in which this work is of justifiable value. Is the value in a more definite knowledge on the part of the student of the fact, for instance, that commercial sodium nitrate contains about 15.5 percent of nitrogen after having made the determination himself than if secured from the printed page alone? It is very doubtful if there is any marked gain in definiteness of knowledge in this particular instance and those of similar nature thru the laboratory determination. Neither would there seem to be any justifiable return to the student from the prosecution of the work involved in securing these results. Again, as in the case of the soil physics work, if the value is here, the course in this respect has no relation to technical agriculture and such returns should be secured from the taking of additional work in general quantitative analysis. In reality it may be questioned whether students should be required to take any work in quantitative chemical analysis unless the expectation is that such work or work

of a closely related nature will form a part of their post-graduate activity. The work in quantitative analysis finds a place in the required work in the curricula of agricultural colleges as a prerequisite to laboratory work in soil fertility. While recognizing a general value of the quantitative analysis work, yet if the need for it as a prerequisite for other work did not exist, would it not be a fair question whether students' time could not be better spent for example in the taking of further work in general chemistry, an introductory course in organic chemistry, or a course in college physics?

Greater value, perhaps, attaches to the work with soil, determination of nitrogen, phosphorus, potassium, and acidity, provided the student works on a soil in which he is interested, such as that from his home farm. Here there is an opportunity for the securing of original information, but with the knowledge most experiment stations have accumulated as to the chemical nature of the soils within their State, the results secured by the average student are likely to give him but little added information and may even not be as reliable as the more general but more accurate data obtained by the station.

The introductory courses in soil biology are not so often required courses. When they are, the laboratory work connected with them is open to the same questioning attitude as that in the courses in soil physics and fertility. Even when the courses are not required, it may be questioned whether the student taking a general course in agriculture should not be given a chance to secure the subject matter of the courses without the laboratory work. Laboratory work also in certain other than the soils courses is likewise open to this same questioning attitude; such, for instance, as the laboratory work in introductory courses in farm crops and in entomology.

It has not been the intention in this paper to present conclusions but to express doubt as to the justifiable value to the students of the usual laboratory work in first or general soils courses as compared with other work which might be taken. In particular, it is desired to raise the question whether it would not be advisable to give this work as separate courses, thus giving opportunity for the securing of the subject matter without the laboratory work and requiring the latter only of men desiring to specialize in soils or closely related work.

NATURAL CROSS-POLLINATION IN MILO.[1]

R. E. KARPER AND A. B. CONNER.

An appreciable amount of natural cross-pollination takes place in grain sorghum, as is evidenced by the hybrid plants which are constantly appearing in fields of this crop. These hybrid plants in grain-sorghum fields are more readily observable than hybrid plants in Indian corn, since the types of grain sorghum are more varied, resulting in more strikingly different hybrids. Very little definite information has been published as to the amount of cross-pollination occurring in grain sorghum. The extent of natural cross-pollination in this crop is of the greatest importance to the plant breeder and to the farmer, as both the improvement and the maintenance of purity are affected by natural cross-pollination. Information as to the percentage of cross-pollination under natural conditions will be an aid to the breeder in attaining higher standards and to the grower of the crop in maintaining the purity of any improved strain.

During the season of 1917 the writers observed some white milo plants which had been mechanically introduced in a plat of yellow milo. These plants were flowering simultaneously with the yellow milo. Forty-one heads of white milo were selected and planted the succeeding year, 1918, in head-row plats, using all seed from each head. No record was made of the number of seed to the head or even the weight of the head. Germination seemed fair, but final counts indicated incomplete germination. From each of these head rows, in which most of the plants produced white heads, all the plants with yellow seed heads were recorded as well as the total number of progeny in each row. The data obtained proved very interesting, notwithstanding the preliminary nature of the work. Table 1 shows the total number of plants and the total number of visible hybrids produced from each head.

It is seen from the table that several heads have shown a much higher percentage of cross-pollination than others, and that such heads invariably have shown about the average number of hybrid plants. Examination of the number of progeny from these same heads as compared to progeny from other heads shows a relatively lower number of progeny plants from these heads which have shown

[1] Contribution from the Texas Agricultural Experiment Station, College Station, Texas. Received for publication April 30, 1919.

TABLE 1.—*Cross-fertilization as shown in the progeny of white milo plants grown under conditions affording maximum natural cross-pollination from yellow milo.*

Head or row No.[a]	Total number of progeny plants.	Number of hybrid plants with yellow seed heads.	Number of hybrid plants not classified as yellow.	Total number of hybrid plants.	Percentage of cross fertilization.
1	330	10		10	3.03
2	570	20	2	22	3.85
3	184	21		21	11.41
4	154	14	1	15	9.74
5	222	26		26	11.71
7	396	36		36	9.09
8	57	8		8	14.03
9	162	18		18	11.11
10	119	5		5	4.20
11	457	13		13	2.84
12	279	21		21	7.52
13	560	57		57	10.17
14	384	22		22	5.72
15	70	18	7	25	35.71
16	397	31		31	7.80
18	203	6		6	2.95
19	358	3	6	9	2.51
20	352	19		19	5.39
21	237	4		4	1.68
22	281	12		12	4.27
23	481	27	1	28	5.82
25	460	22	1	23	5.00
26	990	40	2	42	4.24
27	46	5		5	10.86
30	509	12		12	2.35
31	316	28		28	8.86
32	377	14	2	16	4.24
33	372	13		13	3.49
34	205	16		16	7.80
35	656	19	1	20	3.04
36	635	36	1	37	5.82
37	153	26	2	28	18.30
38	344	16		16	4.65
39	293	15		15	5.11
40	1,236	96		96	7.76
41	585	39	16	55	9.40
All rows	13,430	788	42	830	6.18

[a] Rows 6, 17, 24, 28 and 29 have been omitted for the reason that only a few of the plants came into full head, and hence definite counts were impossible.

a high percentage of natural crossing. This seems to be the case with all heads that show cross-pollination greater than the average of 6 percent. The 16 heads showing more than 6 percent cross-pollination had a total population of 5,022 plants, or an average of 314 progeny plants to the head, while the 20 heads showing less than 6 percent cross-pollination had a total population of 8,409 plants, or an average of 420 progeny plants per head. These data show a

variation in the germinability of the different lots of seed and indicate a proportionate variation in the percentage of cross-pollination due to germination accounted for by the probable increased vigor of hybrid seeds and their consequent persistence in all lots.

Of 830 hybrid plants observed in the entire series, 42 heads were evidently reversions, or were cross-fertilized by pollen from varieties other than yellow milo.

The total progeny of 13,430 plants included 830 first-year hybrids or an average of 6 percent cross-fertilization where the plant was entirely surrounded by others which might cross-pollinate its flowers. If the percentage of the cross-pollination was influenced by germination in these particular lots, then the actual percentage of cross-pollination would be correspondingly lower.

From these results it would seem that in actual field practice where a pure strain is grown near to and flowering at the same time as another field which might contaminate it the amount of crossing in the outer rows would undoubtedly not exceed 3 percent, half of the rate in this case where the white milo plants were entirely surrounded by plants of yellow milo.

CROSS-FERTILIZATION IN ALFALFA.[1]

L. R. WALDRON.

Accurate and detailed knowledge as to the manner and kind of pollination in various farm crops has come to be recognized as basic for intelligent and successful breeding operations. The recognition of the stability of the genotype, at least within the time limits of practical plant breeding, makes it necessary to know as definitely as may be the character of any genotype upon which work is being performed, certainly so far as its zygotic condition is concerned.

A certain amount of work has been done on the maize plant from the above standpoint. With this plant it has been amply determined that when the ordinary genotypic condition is subject to self-fertilization the yields are reduced about 50 percent the first year as shown by Hayes (2) and a reduction of even two-thirds if the self-fertilization is carried thru several generations is shown by Jones (3). Hayes (2) has presented limited data to show the amount of cross-

[1] Contribution from the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak. Approved by the Director. Received for publication August 14, 1919.

fertilization to which an individual maize plant is subject when surrounded by individuals sufficiently distinct to show immediate color differences in the endosperm. Self-fertilization was certainly less than 5 percent. It would be of interest to determine the amount of cross-fertilization when the amount of pollination received by the test plants was provided equally by the two types of plants under trial. In other words, what would be the result if the vicinism were balanced rather than unbalanced?

In alfalfa, conditions of pollination are found differing not only from such normally self-fertilized plants as wheat, oats, and barley but also from the normally cross-fertilized maize plant. The complicated alfalfa flower obviously suggests insect pollination and repeated investigations have shown that certain hymenopterous insects generally play the major part in pollinating alfalfa. While there is little or no argument in regard to this point evidently very few data have accumulated as to the amount of cross-fertilization effected by insect aid. Oliver (5) has pointed out that when an insect releases the tripping mechanism of an alfalfa flower, the stigma, striking the ventral surface of the abdomen of the insect, carries with it some of the pollen of that flower and also picks up foreign pollen from the insect's abdomen provided such pollen is present and properly located. As the insect leaves, it carries away some of the pollen of the newly visited flower.

The writer has depollinated many alfalfa stigmas and in this work has never failed to find the stigma well covered with pollen when released from the keel, however gently such release was brought about. Piper *et al.* (6) have shown that it is not necessary that the pollen cells be imbedded in the surface of the stigma or that the stigmatic cells be ruptured to insure fertilization, as has been claimed by some, and that even the friction of the keel against the stigma carrying the pollen is not an essential feature. In the foregoing work apparently no check flowers were used, so it was not shown that mechanical irritation of the stigma would have been of no benefit. Good fertilization results were secured from strictly static conditions. The general statement may be made that an alfalfa flower freshly pollinated by an insect is surely self-pollinated and also quite possibly cross-pollinated, if the insect has newly come from another alfalfa flower.

Piper *et al.* (6) have also obtained data on the effect of pollen on fertilization secured from various sources. Comparing flowers pollinated by their own pollen with flowers pollinated from flowers of

the same plant there was no appreciable difference relative to the percentage of flowers bearing pods and a doubtful appreciable difference in the number of seeds per pod, of the latter method over the former. However, when alfalfa flowers were pollinated, using pollen from other plants, an appreciable gain in fertilization was noticed, amounting to an increase of approximately 50 percent in the percentage of flowers producing pods. Their figures indicate that cross-fertilization is more efficient in the production of alfalfa seed than is self-fertilization. Further investigationns by them, reported in the same paper, indicate that pollen from *Medicago falcata* is as efficient in fertilizing *M. sativa* as is the pollen from *M. sativa*.

The experiment in hand was designed to secure data on the amount of cross-fertilization occurring between alfalfa plants. The problem is not at all simple and the data presented are admittedly only a first step toward a complete answer. The experiment was not planned to determine the amount of cross-fertilization in any particular plant but rather the amount of cross-fertilization taking place between two groups of plants considered as units. In such work an evenly balanced vicinism would be an important feature. Featuring in this would be the relative abundance of flowers in the two groups of plants, similar habits of growth, similar flowering periods, similar abundance of pollen, etc. If data were to be secured on any considerable number of plants the mere physical limits of the experiment would necessitate such a selection of parents as would allow the determination of parentage in the F_1 generation. This works out nicely when the two parents are *Medicago sativa* and *M. falcata*, the hybrid being strikingly different in flower color than either parent. While this is true, certain characters of these two parents tend to make the vicinism unbalanced. The smaller number of flowers (in my plants), the more or less prostrate habit of growth, and the comparative scarcity of pollen (according to Westgate, 7) of *M. falcata* are perhaps the most important features which tended to unbalance the vicinism between the two groups.

PLAN OF EXPERIMENT.

The stock of *Medicago sativa* used came from Chas. C. Haas, Whitewood, S. Dak. The amount of seed received was small, amounting to less than a gram, and was said to have come from a white-flowered plant. The seed was extremely light in color for alfalfa. The stock of *M. falcata* was secured from Prof. N. E. Hansen, Brookings, S. Dak., as living plants. This is called by Han-

sen (1) Semipalatinsk alfalfa. The plants used in my experiment came into blossom in 1916 and were known to be the true *M. falcata* type before they became a part of the experiment.

The plants entering into the experiment were planted in a rectangular bed 3.5 feet apart in each direction, the plants of the two species alternating in each row. The following diagram indicates the relative positions of the plants in the plat, x representing the plants of one species and o the plants of the other.

```
o  x  o  x  o  x
x  o  x  o  x  o
o  x  o  x  o  x
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The four plants nearest any selected plant were of the opposite type to the selected plant and the four plants next nearest were of the same type. The total number of plants in the plat numbered 117 but the plants of the outside row were used merely as a protective border. The plants were well protected by snow during the winter of 1916–1917 so that they presented a good appearance at the opening of the 1917 growing season. The season of 1917 was favorable to alfalfa seed production. By June 30, 1917, the *M. sativa* was in full bloom and ahead of the *M. falcata* in this respect. The flower color of the *sativa* plants was reasonably uniform and in most cases was a purplish lavender and far removed from the "white-flowered" character which was ascribed to the parent plant of this seed. No trace of variegation in flower color (7) was found in any of the plants.

On June 30 an apparently average *sativa* plant carried 218 flower clusters and the four adjacent *falcata* plants had 7, 28, 33, and 35 clusters, respectively. By August 1 seed was setting with comparative abundance on both types of plants. At this time the number of pods was determined on a typical plant of each group. The *sativa* plant had 85 stalks which bore 10,041 pods while the *falcata* plant had 21 stalks bearing 5,251 pods. The seed from each plant was harvested separately. The comparatively small amount of seed from the *falcata* plants was due in some measure to the dehiscence of the pods as they ripened. The harvested seed was treated with sulfuric acid and planted in flats in the winter of 1918. Some of the *falcata* seed did not germinate well and some of the *sativa* seedlings were killed by damping off but this work as a whole was attended with satisfactory results. The seedlings were transplanted once before planting in the field.

A total of 4,350 plants were planted in the field from May 2 to

7. Cutworms and other causes reduced the stand somewhat in spite of the replanting that was done. Plantings were made at distances of 30 inches each way. The first flowers appeared during the week ending June 27 and notes were taken at intervals of about a week from then on.

In Table 1 are given data as to the amount of hybridity between the two species as determined by the offspring and also the amount of seed produced by the parent plants. The offspring of each plant of 1917 is considered separately.

TABLE 1.—*Quantity of seed produced by parent plants and percentage of hybridization in the F_1 plants of Medicago sativa and M. falcata when grown together.*

Medicago sativa.					*Medicago falcata.*				
No.	Seed produced by parent.	Plants bloomed.	Hybrid plants.	Percentage of hybrids.	No.	Seed produced by parent.	Plants bloomed.	Hybrid plants.	Percentage of hybrids.
	Grams.					*Grams.*			
1	22.8	79	4	5.06	50	4.7	96	54	56.25
2	20.1	7	0	0	51	1.4	88	44	50.00
3	18.4	73	5	6.85	52	1.0	30	15	50.00
4	20.1	36	2	5.56	53	1.4	41	24	58.54
5	40.7	82	6	7.32	55	3.5	76	40	52.63
6	36.9	79	9	11.39	57	.9	56	13	23.21
7	28.8	73	3	4.11	59	1.8	49	18	36.73
8	26.0	82	5	6.10	62	.9	27	7	25.93
9	11.2	68	2	2.94	63	2.3	75	33	44.00
10	38.1	96	4	4.17	64	3.3	74	38	51.35
11	18.0	79	13	16.46	65	2.9	44	17	38.64
12	27.3	74	4	5.41	66	7.8	74	16	21.62
13	21.7	76	3	3.95	67	2.1	73	29	39.73
14	14.5	24	7	29.17	68	6.4	60	16	26.67
15	3.1	17	0	0	69	6.8	75	22	29.33
18	5.5	88	3	3.41	71	3.9	50	19	38.00
19	13.9	80	6	7.50	72	1.6	79	28	35.44
20	18.0	76	5	6.58	73	.9	38	10	26.32
21	33.8	100	2	2.00	75	3.3	80	25	31.25
22	36.2	98	4	4.08	76	1.3	71	39	54.93
23	9.4	93	11	11.83	77	3.5	79	46	58.23
25	7.1	111	15	13.51	78	1.5	74	42	56.76
27	29.6	95	10	10.53	79	5.0	71	39	54.93
29	30.2	49	5	10.20	80	5.4	74	20	27.03
31	17.0	48	8	16.67	82	4.7	81	45	55.56
32	13.3	98	3	3.06	83	4.2	77	29	37.66
33	25.0	55	6	10.91	84	4.1	75	39	52.00
35	22.5	81	8	9.88	85	4.2	75	28	37.33
36	37.9	82	4	4.88					
Totals...	647.1	2,099	157	223.53		90.8	1,862	795	1,170.07
Average..	22.3			7.48		3.2			42.70

In regard to the quantity of seed produced an outstanding difference between *sativa* and *falcata* is noted, as is nearly or quite always the

case, the production per plant of the former being in this instance about 7 times that of the latter. The variation constants of seed production are tabulated below.

	Mean, grams.	Standard deviation, grams.	Variability, percent.
M. sativa	22.31 ± 1.28	$10.25 \pm .91$	45.95 ± 4.85
M. falcata	$3.24 \pm .24$	$1.90 \pm .17$	58.50 ± 6.84

The seed production of the different plants of *M. falcata* is more variable than that of common alfalfa. If the greater variability is of significance it might be accounted for by the fact of pod dehiscence, which factor might act unequally among the various plants.

It is well to compare the quantities of seed produced with those obtained by Oakley and Garver (4) as an average for four years, in South Dakota. With them *M. sativa* yielded 2.19 grams per plant and *M. falcata* 0.35 gram. While the absolute quantities in the present experiment are much in excess over those quoted, the relative quantities are about the same.

Of the 2,099 plants coming into bloom certainly having *M. sativa* for a pistillate parent, 157 indicated certain *falcata* flower color characters and were of hybrid origin. The percentage of hybrid plants is thus 7.48. Of the 1,862 blooming plants with *M. falcata* for a pistillate parent, 795 showed *sativa* flower characters and so were of hybrid origin, the percentage of hybridity thus being 42.70.

Using the percentage hybridity means as a series of variates the constants of variation were found to be as follows:

	Mean, percent.	Standard deviation, grams.	Variability, percent.
M. sativa	$7.71 \pm .74$	$5.89 \pm .52$	76.39 ± 9.96
M. falcata	41.79 ± 1.53	12.04 ± 1.09	28.81 ± 2.80

The unweighted mean is larger in one case and smaller in the other, than the corresponding weighted means. What is more to the point is the much greater variability in *M. sativa* than in *M. falcata.* It is not clear why this disparity should exist.

The foregoing means indicate that the *falcata* plants of the parent plat were cross-fertilized to a much greater extent than were the corresponding *sativa* plants. Westgate (7) grew *M. falcata* alongside ordinary alfalfa. The resulting offspring plants, evidently coming from the *M. falcata* seed, were said to be hybrids, the implication being that the hybridity was 100 percent. "In other experiments, the progeny of ordinary alfalfa grown associated with *M. falcata* has not shown any indication of *M. falcata* parentages." In

this case the *falcata* plants were comparatively few in number. In my experiment all the 1917 *sativa* parent plants produced some hybrid offspring except two and in both these instances but few plants were produced.

The marked disparity of hybridity percentages in the reciprocal cross-fertilization secured by me indicates a rather strongly unbalanced vicinism. This disparity was due in part to the difference in number of flowers between *M. sativa* and *M. falcata* and also to the comparative scarcity of pollen in *M. falcata*. It is evident that the results do not give a true criterion of the amount of cross-fertilization occurring between two alfalfa groups more properly balanced from a vicinal standpoint than the ones under trial. If the *falcata* plants had had more blossoms and a greater abundance of pollen, it seems likely that the percentage of hybridity would be located more centrally between the two extremes of 7 and 43 percent.

It is evident, as previously indicated, that this experiment furnishes no measure of the amount of cross-fertilization undergone by any particular plant against all the remaining ones. Other experiments would have to be carried out to furnish data on this point.

CORRELATION BETWEEN SEED PRODUCTION AND HYBRIDITY.

Correlation coefficients were worked out between seed production and percentage of hybridity. The correlation was negative in both cases. For the *M. sativa* group it amounted to $-.14 \pm .12$ and for the *M. falcata* group, $-.20 \pm .12$. These coefficients are scarcely significant taken each by itself but their negative character in both cases strengthens the probability of the correlation as it appears.

Assuming there is a real negative correlation, this would mean that the plants producing the smaller seed crop in 1917 were cross-fertilized in greater measure. Or, an increase in the amount of cross-fertilization had an adverse effect upon seed production. This would seem to indicate a certain interspecific nonadaptability of pollen with the plants under experiment. The work of Piper *et al.*, already cited, indicates that the pollen of *M. falcata* in fertilizing *M. sativa* is as efficient as that of *M. sativa* itself.

Scarcely figuring as a part of this experiment is the character of the flower color of the *M. sativa* plants. Out of the 1,943 *M. sativa* plants which bloomed, there were 20 plants, or about 1 percent, which bore white flowers as the grandparent plant was said to do. A total of 12 plants produced the 20 white-flowered offspring. Some self-fertilized seed from the white-flowered plants was very light in color, the same as the seed from the grandparent.

SUMMARY.

In the foregoing experiment the two species of Medicago, ***sativa*** and *falcata,* were planted together in equal numbers to secure data on the amount of cross-fertilization taking place between the two species.

Flowering records in the F_1 generation showed that the gametes of the *M. sativa* parent plants had united with gametes from the *M. falcata* plants to form mature sporophytes from *M. sativa,* to the extent of 7.48 percent. From *M. falcata* 42.70 percent of hybrid plants were produced. The disparity was due probably in the main to the comparative scarcity of both flowers and pollen in *M. falcata.*

A slight, but perhaps significant, negative correlation was found to exist between amount of seed produced in the parent plants and the extent of cross-fertilization.

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AGRONOMIC AFFAIRS.

NOTES AND NEWS.

Alfred Atkinson, agronomist of the Montana college and station, has been elected president of the Montana State College. He succeeds James M. Hamilton, president during the past fifteen years, who has resigned to become professor of history and economics in the same institution.

F. W. Brown, recently in charge of investigations of fertilizer resources of the United States in the Federal Bureau of Soils, is now executive secretary of the United States Potash Producers' Association, with headquarters in Washington, D. C.

W. W. Burr is now assistant director as well as agronomist of the Nebraska station and during the recent absence of Dean Burnett on educational work in France was acting dean and director.

E. O. Fippin, extension professor of soil technology in Cornell University, has been granted a year's leave of absence, during which time he will act as director of the agricultural bureau of the National Lime Producers' Association.

A. J. Galbraith, professor of chemistry of the Manitoba Agricultural College, died in December, 1918. At the time of his death he was engaged in a soil survey of Manitoba.

L. F. Locke has succeeded L. N. Jensen as representative of the Federal office of dry-land agriculture at the Amarillo (Texas) Cereal Field Station.

F. B. Mumford, dean of the Missouri college of agriculture, is the agricultural representative of a commission of American universities to visit France with a view to cementing more closely educational and economic relations between the two countries. M. F. Miller is acting dean and director in his absence.

J. J. Skinner of the Federal Bureau of Plant Industry has been awarded the Edward Longstreth medal of merit by The Franklin Institute, for his paper, "Soil Aldehydes," which appeared in the Journal of The Franklin Institute from August to December, 1918. In presenting the medal, the Committee on Science and the Arts said: "These papers present the results of scientific study of a new class of

deleterious soil constituents, clearly described and effectively illustrated, the whole forming a valuable contribution to the science of agricultural chemistry, and one of marked practical importance."

C. E. Trout, formerly of the Federal office of corn investigations, is now doing vocational agricultural work in the Jersey Township High School at Jerseyville, Ill.

Harry Umberger, acting dean of extension in Kansas since January 1, on July 1 was made dean of extension.

The Agricultural Index, begun in 1916, has now published a 3-year cumulation of all references to agricultural literature appearing in its pages during 1916, 1917, and 1918. This volume contains 1,056 pages, with 70,752 references. Not only are all Federal and State publications on agriculture included, but also 78 farm papers and technical journals, among the latter being the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY.

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TILLAGE: A REVIEW OF THE LITERATURE.[1]

M. C. SEWELL.

INTRODUCTION.

The largest item of expense in producing cereal and annual forage crops is tillage. The most important tillage operations are plowing and cultivation. Any reduction in the depth of plowing, frequency of plowing, or number of cultivations necessary for economic yields materially reduces the cost of raising the crop. The prevailing opinions are so conflicting regarding plowing and cultivation that a review of the literature seems desirable to determine what conclusions can be drawn from the written evidence on the subject.

EARLY HISTORY OF TILLAGE.

The history of tillage begins with the earliest written records of mankind. Sculpturings on the ancient Egyptian pyramids represent the use of the scarcle, a man-power tillage implement of the chopping spade type. Other sculpturings, 4,000 years old, depict a wooden plow drawn by animals.

One writer ascribes the origin of tillage to the wild boar and the observation of ancient races that plants flourished in ground previously rooted by wild boars (38).[2] The first tilling of the soil was no doubt practised in order to enable the husbandman to get his seed or plant into the soil. The second step in soil stirring was occasioned by the necessity of combating intruding weeds. The agriculture of

[1] Contribution No. 16, Agronomy Department, Kansas Agricultural Experiment Station, Manhattan, Kans. Received for publication June 23, 1919.

[2] Figures in parentheses refer to "Literature cited," p. 287.

Greece and Rome was founded on the theory that working of the soil was necessary because of the intractable soil and incursion of weeds. Virgil advocated good tillage. Since that period it has been believed that the soil is actually benefited by loosening and stirring (1).

The Early Philosophy of Tillage.

Very little seems to be known of agricultural development during the middle ages. Until 1731, when Jethro Tull published his "New Horse-Houghing Husbandry" (59), there had been no discussions of soil tillage since the time of Virgil. Tull, an English landlord, while traveling in southern Europe observed the tillage between vineyard rows. On returning to England he adapted the system to the row culture of cereal crops. He believed that the earth was the only food of plants; that the plant fed by taking in minute particles of earth, which were disengaged from the surface of the soil grains. Consequently, according to his theory, the more finely the soil was divided by tillage, the more numerous would be the particles that could be absorbed by the roots of plants. Insufficient tillage would leave the strong land with its natural pores too small and its artificial ones too large, while it would leave light land with its natural and artificial pores too large. As to weeds, he stated that they starve the plants by robbing them of their provision of food. Weeds never all come up in one year unless the land is often plowed. The best defence against these enemies, in his opinion, was a good summer fallow.

Tull ascribed the benefits of manures to the dissolving and crumbling effect they had on the soil. To this extent his theory was anti-Virgilian. According to the latter, land was pulverized by fire, and dung and harrows were used in place of the plow. The husbandry of England, especially along the southern coast, which was inhabited by Romans, was of this kind at the time of Tull's writing.

With the beginning of the nineteenth century, development in the science of agricultural chemistry thru the work of Priestley (45), de Saussure (51), Davy (11), Boussingault (3), and Liebig (36), laid the foundation for the conception of the nutrition of plants as being based on the assimilation of certain chemical elements from the soil minerals, organic matter, water, and air. From this period the idea developed that tillage, by increasing the aeration of soil, increased oxidation of chemical compounds in the soil, rendering them more soluble in the soil solution.

Gaylord (18), of Onondaga, N. Y., writing in 1841, states that the end to be gained by tillage is the more effectual pulverization of the

soil and mixing it together so as to insure the united action of the whole in the production of the crop. Tillage, he claims, enables us to change the character of the soil in relation to moisture, temperature, and fertility.

At a meeting of the New York Agricultural Society at Albany in 1849, Lee (35), an editor from Augusta, Ga., presented the view that exhaustion of the soil is promoted by excessive plowing and hoeing. He believed that two-thirds of the tillage in the United States, especially in the southern States, impaired the natural fertility of the soil. He attributed this to the greater oxidation of organic matter on the tilled land and to the leaching of the soil of its soluble mineral elements.

The importance of deep tillage and subsoiling was brought to the attention of the Maine Department of Agriculture by Goodale (20) in 1860. It was his opinion that these practices allowed roots to penetrate deeply in search of food and moisture. The idea that the soil contains the necessary supplies of mineral matter and that tillage operations are capable of rendering these supplies available was discussed by Goodale (21) in 1861 before the meetings of the Maine Department of Agriculture.

Tanner (57) of Ohio, writing in 1861 of the mechanical conditions of the soil favorable for the growth of seed, states that the cultivator of the soil will find in the preparation of the land for the reception of seed his most laborious duty and that which demands his greatest judgment and skill. With heavy soil he found an early preparation advisable so that it can be thrown together in a dry state after which it remains untouched until seed time.

The cultivation of field crops and preparation of soils was discussed by Turner (60) in 1866 with reference to why plowing or cultivation of the soil is beneficial. He pointed out before the Maine Department of Agriculture that the old theory that tillage increases crop production by mixing ingredients already in the soil and presenting them more readily to roots is false. Since nine-tenths of plant substance comes from the atmosphere and since the roots of wheat extend 5 feet in depth and corn roots 10 feet, scratching the surface with plows and cultivators could be of small benefit. According to his view, the real end in plowing is to put the soil in such condition that the plant may most readily absorb energy from the sun, and the moisture and other food elements from the air and soil.

The view was presented by Sweet (55) of Maine in 1871 that an important result of tillage is the control of weeds. He quotes several

experiments conducted in England in which weeds reduced the crop to a large extent.

According to Johnson (26), in an address before the Connecticut Board of Agriculture in 1877, the tendencies in most soils is towards mechanical compacting and chemical petrifaction. One of the important offices of tillage, he claimed, is to counteract these tendencies. He pointed out the effect of tillage in modifying the storage of water in the soil by changing the arrangement of the soil particles. He also recognized the necessity of different treatments for different soils.

That root pruning explains in part the beneficial results of tillage was the belief of Sturtevant (54) in 1877, as expressed to the Connecticut Board of Agriculture. Experiments in which corn plants grown in water cultures and in pot cultures were pruned, showed that pruning of the roots by checking their growth stimulated seed production. Cultivation, however, was found injurious if carried beyond the flowering stage of the plant.

Davenport (10), in discussing the preparation of the soil for cereal crops in Maine in 1881, stated that the primary object of tillage was to stir and pulverize the surface of the soil that has been hardened and packed by rains. He believed that the finer the soil the more surface there is to hold moisture and for the action of the roots and that a well-cultivated soil seldom suffers from drouth. When wheat followed oats Davenport advocated plowing as soon as possible after harvest, and keeping the surface clean and loose thereafter.

Under Missouri conditions, Waters (63) pointed out in 1887 that sod prevents surface washing and that excessive tillage increases it. The latter condition, he believed, is brought about by rapid oxidation and decomposition of vegetable matter induced by the circulation of air in the soil as a result of the cultivation.

An English writer, Walden (61), in 1891 advocated thoro tillage and gave as his opinion that a skillful farmer requires comparatively little extra soil stimulant in the form of dung to grow a successful crop. His belief that "implements make the best manuring" is not very far from the truth.

Up to this period, literature on tillage has given only conflicting views upon the subject. From this time, experimental results were published which give more definite information.

Preparation of Seedbeds.

Morrow and Gardner (42) of Illinois compared in 1892 the yields of corn on seedbeds plowed at depths varying from 2 to 10 inches. Their results are given in Table 1.

TABLE 1.—*Yield of corn from seedbeds plowed to various depths.*

Treatment, 1888 to 1893.	Yield in bushels per acre.	Treatment, 1890.	Yield in bushels per acre.
Not plowed; disked shallow	56.4	Plowed 2 inches deep	54.0
Plowed 2 inches deep	59 9	Plowed 5 inches deep	57.5
Plowed 4 inches deep	69.4	Plowed 10 inches deep	56.0
Plowed 6 inches deep	69.3		
Plowed 8 inches deep	71.1		

None of these plots had any cultivation after planting, except removing the weeds by scraping the surface with a sharp hoe. The soil was one easily worked. It was loose, porous to considerable depth, and had great capillary attraction. They concluded that deep stirring of the soil for a crop is unnecessary and that air, water, and the roots of corn readily find their way into the soil even if it has not been stirred.

In experiments with corn at the Indiana experiment station, Latta (32) found practically no difference in yield from plots plowed 8 inches deep as compared with 4- to 4.5-inch plowing. These results were averages of yields obtained from 1886 to 1891, excluding the year 1887 when no yield was obtained. In another experiment conducted for two years, 1891–1892, there was practically no difference in the yield from plowing 6, 8, 10, and 12 inches deep. Plowing 4 to 4.5 inches gave slightly smaller yields.

The Indiana station (33) gives the average results for four years of the plowing experiments begun by Latta in 1891. These data are presented in Table 2.

TABLE 2.—*Average yields of corn produced at the Indiana station on land plowed to various depths in the four years from 1891 to 1894, inclusive.*

Depth of plowing, inches.	4	6	8	10	12	14	16
Yield in bushels per acre	33.77	34.19	35.14	34.49	35.00	34.84	34.14

According to these averages there was a slight increase in yield with depth of plowing up to 8 inches.

Sanborn (50), in 1892, compared different depths of plowing for wheat at the Utah experiment station. A plot was also included which had not been plowed. This plot was raw sage brush land and the sage brush was cut off level with the surface without stirring the soil. The wheat was planted with a hoe and at the same depth as in the other plots. The results are incorporated in Table 3.

TABLE 3.—*Average yields of wheat obtained in a depth-of-plowing experiment at the Utah station.*

Depth of plowing.	Average yield per acre for three years. Grains in bushels.	Straw in pounds.
Not plowed	8.6	1,013
Plowed 4 inches deep	14.1	1,101
Plowed 6 inches deep	13.3	1,113
Plowed 8 inches deep	14.7	1,117
Plowed 10 inches deep	14.4	1,317

The unplowed plot gave the lowest yield, but there was only a slight difference in the yield from the other treatments. Similar results were secured in a later experiment (49). There was, however, an increase in yield of straw with the depth of plowing.

Merrill (39) conducted experiments in which the effect of depth of plowing on the yield of dry-land wheat was compared for five years at four different branch experiment stations in Utah and at one of them for an additional two years. The yields as reported in 1910 are given in Tables 4 and 5.

TABLE 4.—*Average yields of wheat obtained in depth-of-plowing experiments conducted on four experiment farms in Utah during the five years from 1904 to 1908, inclusive.*

Treatment.	Average yield in bushels per acre. Juab County farm.[a]	Washington County farm.	Tooele County farm.	Sevier County farm.
Plowed 8 inches deep	23.3	11.6	14.7	5.3
Plowed 10 inches deep	23.4	12.0	14.9	5.8
Plowed 15 inches deep	16.9	15.2	14.8	6.8
Plowed and subsoiled 18 to 20 inches deep	15.4	15.2	16.2	6.4

[a] Heavy clay soil.

TABLE 5.—*Annual and average yields of wheat obtained in tillage experiments on the Washington Co., Utah, experiment farm in 1907 and 1908.*

Treatment.	Yield of wheat in bushels per acre. 1907.	1908.	Average.
Disked, not plowed	27.9	13.9	20.9
Plowed 5 inches deep	25.0	13.3	19.1
Plowed 12 inches deep, not subsoiled	29.3	26.0	27.7
Plowed 16 inches deep, not subsoiled	33.7	21.0	27.4

In Washington County the results favor deep plowing. In all others nearly as good yields were secured from 8-inch as from deeper plowing.

In experiments conducted by G. W. Waters (62) in 1893 at the Missouri station, subsoiling did not give better yields of corn than plowing 7 inches deep.

In experiments at the New York station as cited by Waters, 6-inch plowing in one experiment gave better yields than plowing 12, 18, or 24 inches deep and nearly as high yields as plowing 30 inches deep. In still another experiment, 4-, 6-, and 8-inch plowing gave about the same yields, which were somewhat better than were secured from disking alone or from 2- to 4-inch plowing.

Kraus (31) decided in 1894 that the greatest influence exerted upon the production of plants is the spacing, the second the effect of manuring, and the third the depth of plowing. These conclusions were based upon experiments at Weihenstephan, Germany, in which plants were seeded in wide and in narrow rows, with manured and unmanured treatments on both shallow and deep plowing.

Wollny (67), in publications at München, Germany, in 1895, compared six treatments of the soil in field plots 4 meters square. The experiment included two plots each of three tillage treatments—unworked, plowed 18 cm. deep, and plowed 36 cm. deep, one plot of each being fertilized and one unfertilized. The fertilizer used was guano applied at the rate of 200 gm. per plot (500 kg. per hectare). The soil was a calcareous loam containing 4.5 percent humus and 2 percent calcium. During the four years previous to the experiment the field had grown potatoes and had been well fertilized. The experiment was conducted for three years, the crops grown being spring rye, maize, rape, flax, peas, sugar beets, potatoes, and horse beans. Wollny concluded that loosening of the soil increased its productiveness and this increase in a majority of the cases was considerable. The increase was relatively small for rye, peas, horse beans, and flax; and was relatively large for maize, rape, sugar beets, carrots, and potatoes. The fertilizer was most effective on the deep-plowed plots. According to Czerhati (9), cited by Wollny, the increase in yield from deep plowing for oats and barley was less than for maize. Kühn was cited as having conducted experiments in which it was found that plowing a sandy soil which contained but little humus to a depth of 45 cm. produced almost as much barley as a soil plowed only 10 cm. deep.

Later experiments by Wollny included an unworked treatment with the deep and shallow working of the soil. The results obtained did not occasion any change in the conclusions drawn from the previous work.

Tancré (56), a German investigator, advocated plowing immediately after harvest. Regarding the weathering of soils, he considered the winter as the time of crumbling; the spring as the time of solubility; and the summer as the time of fermenting of manure.

In experiments at the Kansas station (19), in 1895–6, surface plowing for corn produced 34.0 bushels and subsoiling 33.4 bushels per acre.

Shepperd and Jeffrey of the North Dakota Agricultural Experiment Station (53) reported, in 1897, the average yields of wheat for two years obtained by different methods of tillage. Plowing with a disk gang plow yielded 50 pounds less per acre than plowing with a moldboard. Subsoiling gave an increase of 39 pounds per acre but at a much greater cost. Deep plowing (8 inches deep) produced 43 pounds per acre more than shallow plowing.

Lyon (37) investigated the effect on the corn crop of deep plowing and subsoiling in Nebraska. Of 59 replies from questionnaires sent to farmers in Nebraska operating on clay subsoil, 80 percent favored subsoiling. Of those having a loam subsoil, 23 percent favored subsoiling. Reports from western Nebraska, where the soil and subsoil are porous, showed that subsoiling reduced the yields. In 1896 and 1897 shallow plowing (4 in. deep) both in the spring and fall gave better yields than deep plowing (8 in. deep), but disking gave lower yields than shallow plowing.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio experiment station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Farrar and Sutton (16) reported in 1906 of different depths of plowing with disk and with moldboard plows on the yield of wheat, with fertilizer and without fertilizer in New South Wales. The average yields obtained are presented in Table 6. The moldboard

TABLE 6.—*Average yields of wheat in bushels per acre with different depths of plowing in New South Wales.*

Depth of plowing, inches.	With fertilizer.		Without fertilizer.	
	Disk plow.	Moldboard plow.	Disk plow.	Moldboard plow.
4	9.7	14.5	9.7	13.3
6	8.6	16.3	8.5	15.4
8	10.2	16.5	10.7	14.8

plow gave the highest yields in all cases. Eight-inch plowing gave higher yields than shallower plowing in most cases but the difference was small, probably not enough to pay the extra cost.

Reitmair (46) in 1905 compared deep plowing (27 cm. or 10.6 in. deep) with shallow plowing (15 cm. or 5.9 in. deep) for several different crops. In all cases the deep plowing produced larger yields, the difference for oats being 27.8 bushels; beans for hay, 0.22 ton; and potatoes 6.3 bushels per acre in one instance and 32.5 bushels on a duplicate plot. Reitmair points out that there was not any essential difference in the nitrate supply of the deep-plowed field compared with the other and he could not explain the wide variation in the yields of the duplicate plots of potatoes.

Kaserer (27) at Vienna, Austria, in 1906 compared plowing with the treatment of loosening the soil without plowing, on a sandy loam soil. Three plots were worked 20 cm. (7.8 in. deep) for beets with an extirpator, while two plots were plowed 20 cm. deep and left rough over winter. The two methods of preparation were also compared for wheat, barley, and corn. There was no material difference in the nitrogen content of the plots and no material difference in yield except for corn. For this crop, the results were much in favor of deep plowing.

As an average of 40 trials during a period of three years at the experiment station at Davis, Cal., Shaw (52) found an average difference of about 8 bushels of wheat and 6 bushels of barley in favor of deep plowing as compared with shallow plowing. The effect appeared to extend to the following crop, an average difference of 8 bushels in the following crop of barley being observed.

Baring (2) states that in tillage experiments in New South Wales, subpacking does not appear to increase the yield. Subsoiling and deep plowing failed to give increased yields, subsoiling apparently resulting in lower yields. The disk plow gave slightly better returns than the moldboard plow.

Noll (44) reported in 1913 on the results of three years' tests of deep (12-inch) plowing and ordinary (7.5 inch) plowing at the Pennsylvania station. The yields of corn, oats, barley, wheat, alfalfa, clover, and timothy were compared. These crops were grown in rotation. The average yields, including more recent data as yet unpublished, but kindly furnished the writer, fail to show any advantage for the deeper plowing. The average yields for 1910–1913 are presented in Table 7.

TABLE 7.—*Average yields of grain in pounds per acre of various crops under various tillage methods at the Pennsylvania Agricultural Experiment Station during the four years from 1910 to 1913.*

Crop.	Number of years grown.	Yields in pounds per acre.	
		7.5 inch plowing.	12-inch plowing.
Corn	3	4,128	3,957
Barley	1	835	792
Oats	2	1,059	1,086
Wheat	2	1,240	1,281
Alfalfa	3	2,716	2,774
Clover and timothy	2	4,537	4,483

The draft per square foot of cross section of the furrow was determined and was found to average 1,113 pounds for the 12-inch plowing and 724 pounds for the 7.5-inch plowing.

Wright (70), in 1914, reports five years' results with plowing experiments at the Oklahoma station in which 7-inch plowing gave the highest yield. There was no difference between the yields from 7-, 8-, and 9-inch plowing. Subsoiling was unprofitable. The soil was an upland silt loam with an impervious subsoil.

Williams and Welton (66), reporting in 1915, compared the average yields for deep plowing, ordinary plowing, and subsoiling for corn, oats, wheat, and clover for a period of five years. The yields are presented in Table 8.

TABLE 8.—*Average yields of various crops under various tillage treatments at the Ohio Agricultural Experiment Station in a 5-year test.*

Crop.	Treatment.		
	Plowed 7.5 inches.	Plowed 15 inches.	Subsoiled.
Corn (bu.)	60.69	61.12	63.01
Oats (bu.)	45.49	43.80	45.11
Wheat (bu.)[a]	33.14	33.37	34.18
Clover (tons)	2.43	2.35	2.34

[a] Average for four years only.

The results show that there is not a consistent difference in favor of deep plowing or of subsoiling.

Cardon (6), in a report on dry-land tillage experiments at Nephi, Utah, states that there was not any material difference in yields obtained from plots plowed at depths varying from 5 to 18 inches. There were eight plots employed, four being cropped each year and four fallowed. The depths of plowing for fallow were: (1) Subsoiling 18 inches; (2) subsoiling 15 inches; (3) plowing 10 inches;

and (4) plowing 5 inches. Regarding soil moisture, it was found that there was no advantage in deep plowing or subsoiling, for the moisture content of the 5-inch plowing was as high as that of any of the other deeper treatments.

Chilcott and Cole (8) concluded in 1918 that, as a general practice, no increase of yields or amelioration of conditions can be expected from subsoiling or other methods of deep tillage for the Great Plains as a whole. These conclusions are based on results of extensive experiments covering a wide range of crops, soils, and conditions, in ten different States in the Great Plains. The authors very aptly sum up the function of plowing in the following statements:

It is mistaking or failing to recognize the purpose of plowing that leads to the belief that its efficiency increases with its depth even though that depth be extended below all practical limits of cost and effort. Plowing does not increase the water holding capacity of the soil, nor the area in which roots may develop or from which the plants may obtain food. Plowing removes from the surface either green or dry material that may encumber it, provides a surface in which planting implements may cover the seed, and removes or delays the competition of weeds or plants other than those intended to grow, and in some cases by loosening and roughening the immediate surface, checks the run-off of rain water. All of these objects are accomplished as well by plowing to ordinary depths as by subsoiling, dynamiting, or deep tilling by any other method. There is little basis, therefore, for the expectation of increased yields from these practices, and the results of the experiments show that they have been generally ineffective.

Miller (41), in a study of the root systems of corn and the sorghums, isolated roots of these plants to a depth of over 6 feet and found the root development more extensive below the surface foot area of soil than above. From this fact, we may judge that deep plowing does not effect the depth of root penetration.

TABLE 9.—*Effect of depth of plowing on yield in a rotation of corn, oats, and wheat at the Kansas Agricultural Experiment Station during the six years from 1913 to 1918, inclusive.*

Treatment.	Average yield in bushels of grain per acre.		
	Wheat.	Corn.	Oats.[a]
Plowed July 15, 12 inches for wheat...	24.6	22.1	34.7
Plowed July 15, 7 inches for wheat...	24.2	24.0	37.6
Plowed July 15, 3 inches for wheat......	24.9	22.9	38.2

[a] Average for five years, no grain yield in 1916.

Unpublished data of the Kansas Agricultural Experiment Station from the wheat seedbed rotation project do not give any appreciable

differences in yields in 3-, 7-, and 12-inch plowing. These conclusions are based on the averages of six years' results. In this rotation, the wheat stubble is plowed in the fall 6 to 7 inches deep for corn, the corn stubble is disked in the spring for oats, and the oat stubble is plowed various depths for wheat. Table 9 presents the yields from this project.

The Kansas station also has eight years' results with wheat cropped continuously under different seedbed treatments. The average yields are presented in Table 10.

TABLE 10.—*Average yields obtained from various methods of seedbed preparation on land cropped continuously to wheat at the Kansas Agricultural Experiment Station in the eight years from 1911 to 1918, inclusive.*

Treatment.	Average yield in bushels per acre.
Disked at seeding time	6.8
Plowed Sept. 15, 3 inches deep	12.7
Disked July 15, plowed Sept. 15, 7 inches deep	17.5
Disked July 15, plowed Aug. 15, 7 inches deep	18.2
Listed July 15, ridges worked down	17.5
Listed July 15, ridges split Aug. 15	17.4
Plowed July 15, 7 inches deep	20.8
Plowed Aug. 15, 7 inches deep, worked immediately	19.5
Plowed Aug. 15, 7 inches deep, not worked until Sept. 15	18.1
Plowed Sept. 15, 7 inches deep	13.5
Plowed July 15, 3 inches deep	16.4

These results show a decided benefit in the deeper early plowing (7 inches) over the shallow early plowing (3 inches) when wheat is grown continuously on the same land. Except in dry summers, the stubble on the August and September plowed plots is weedy unless it has been disked after harvest time. Moisture and nitrate determinations conducted in connection with this tillage project have led to the conclusion that early plowing is beneficial because it prevents weed growth and thus conserves available soil moisture and plant food (4).

The conclusion is drawn from the references discussed under this head that deep plowing (more than 7 inches deep) in general does not increase crop yields. The question left unsettled is the depth of plowing less than 7 inches that produces the best results and the necessary frequency of plowing that depth.

The Cultivation of Crops.

EFFECT ON SOIL MOISTURE, NITRIFICATION, AND YIELD.

Intertillage of crops has been practised because it has been considered beneficial aside from the control of weed growth. The general belief has been that cultivation conserved moisture by maintaining a soil mulch and, by aerating the soil, developed available plant food, thus promoting bacterial and chemical changes.

Sanborn (49) found in his tillage investigations in Utah in 1893–1894, that the difference in moisture between land plowed and unplowed was 0.63 percent in favor of the plowed.

Grandeau (22), in 1894, in discussing the advantages and effects of deep cultivation in French agriculture, stated that old tillage practices result in a lighter, better aerated soil, and that the capillary capacity of the soil is increased. These results, he believed, increased the nitrifying power of the soil, maintained the humidity of the surface soil in a more favorable condition for vegetation, and made the nutritive elements available by placing the radicles of plants closely in contact with the soil particles. Deep working during the summer was found to double the amount of water contained in the soil as compared with soil not worked.

Kraus (31), in 1894, found the results of deep and shallow working of corn and beets in Germany to favor the deep working.

Miller and Brinkley (40), in 1897, reported yields of corn at the Maryland experiment station under deep and shallow cultivation. The depths were 6 to 7 inches and 2 to 3 inches. There was a gain of 2.4 bushels in favor of deep cultivation. They state that this gain was not enough to pay for the extra cost.

Wollny (69) published an article in 1897 on the influence of the mechanical working of the soil upon its productiveness. Previous experiments at München, Germany, had shown that loosening the soil made it accessible to air and more easily saturated, but the effect of a pulverized condition had not been investigated. The crops grown in this experiment were flax, red clover, lucerne, and grass mixture. Yields were obtained four different years. The first experiments conducted in pots were verified by field plots on a clay loam soil. The plants without exception attained higher production in the crumbly soil than in the pulverized. Consequently, Wollny decided that the crumb structure characterized the condition of the soil to be striven for in a rational system of agriculture.

The effect of loosening the soil upon the nourishment contained in

the soil was also investigated by Wollny (69). Crumbly and pulverized soils, fertilized and unfertilized, were compared. For fertilizer a mixture of equal parts of superphosphate, calcium chloride, and Chili saltpeter was used. The data show that the action of the fertilizer on the crumbly soil is greater than on the pulverized.

In discussing farm practices that maintain the soil in a normal condition of structure, Wollny stated that tillage should take place immediately after harvesting the crop, otherwise the loose condition of the soil is lost after the crop covering is cut and the soil exposed to atmospheric precipitation.

In answer to the question of when and how often the soil should be worked, Wollny concluded as a result of one year's experimentation that fields requiring cultivation in the spring should be plowed in the fall; that altho under certain conditions repeated workings of the soil in the spring were profitable, in the spring and summer land should be worked only when in a medium degree of moisture because with a higher or less degree of moisture the crumbly condition of the soil would not result.

Wollny also conducted experiments to determine the effect of hoeing upon plant production and the relation between the effect of loosening and the destruction of weeds without cultivation. He concluded that hoeing exercises a favorable effect upon plant production when practised on land loosened in the fall, but that it often proved injurious in its effect when the soil was in good mechanical condition and a long dryness simultaneously prevailed.

The comparison of the hoed and the not hoed but weeded treatments proved that the production of plants was increased thru the surface loosening, but that hoeing culture attains its greatest success primarily by the destruction of weeds.

The action of fertilizers was found by Wollny to increase with the depth of the tilled stratum, fertilization with the deeper degrees of tillage producing the greatest yields.

In a later publication, Wollny (68) determined the properties of coherence, adhesion, and friction of soils. The data presented by him emphasize the advantage of the crumbly condition of the soil.

Dehérian (13), working under French conditions, compared the amount of moisture collected from drainage under the condition of vegetation compared with fallow. The average yearly percolation for three years was 417 liters from the soil without cultivation and 440 liters from the soil cultivated. He concluded that loosening the soil favors the penetration of moisture.

In 1897 Shepperd and Jeffrey (53) reported for the North Dakota Agricultural Experiment Station the average yields of wheat for two years obtained by different methods of tillage. Seeding in cultivated drills 24 inches apart produced 10.2 bushels less per acre than wheat sown in the ordinary way without cultivation. On fall plowed and spring plowed ground, there existed a slight difference in favor of shallow plowing as compared with deep.

Dehérain (14, 15), in 1900, inspired by the old proverb "two ploughings are equal of an irrigation," attempted to show experimentally why this may be true. His experiments were directed mainly to determining the effect of a soil mulch in retarding the loss of water by evaporation. Moist soil was placed in vessels which were weighed at intervals to determine the loss. A soil mulch was maintained by covering the surface with dry soil or by cultivation. The differences in the loss of moisture were insignificant in most cases and Dehérain concluded that a soil mulch has little effect in retarding evaporation. In later experiments he found that plants growing in the soil were the principal means by which water was removed. He advanced the idea that plowing and weeding were of equal value.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio Agricultural Experiment Station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Welborn (64), in 1908, compared the yield of corn and cotton grown with deep (6-inch) and with shallow cultivation at the Texas Agricultural Experiment Station. He failed to find any advantage for deep cultivation.

Knight of the Nevada station (30) compared in 1908 the effect of mulches of different depths on checking the loss of water by evaporation. Soil containers were used, and the dry earth mulch was applied to the wetted soil. The effect is shown in Table 11.

TABLE 11.—*Soil container experiments with mulches.*

Depth of mulch.	Water loss in inches.	Percentage of the total water loss.
Water surface	4.68	78.0
No mulch	1.41	23.6
3-inch mulch	.88	14.6
6-inch mulch	.36	6.0
9-inch mulch	.17	2.9

In this experiment where the mulch consisted of dry soil applied to the wetted soil, the soil mulching was effective and increased in

efficiency with the depth. However, another experiment is reported by Knight in which the soil containers were irrigated and the soil mulch established by cultivation. Compared with a water surface loss of 8.49 inches, the soil surface cultivated 6 inches in depth lost 1.09 inches of water and the uncultivated soil, 1.51 inches. In this instance, the difference in loss is not great.

Cates and Cox (7), in 1912, tabulated the results of 125 experiments carried on for six years, 1906–1911, in 28 different States. They concluded that cultivation is not beneficial to the corn plant except in the removal of weeds.

Mosier and Gustafson (43), in 1915, showed as a result of eight years' work at the Illinois Agricultural Experiment Station that killing weeds without cultivation produced a gain of 17.1 percent or 6.7 bushels per acre over ordinary cultivation (shallow three times).

Thom and Holtz (58) found at the Washington Agricultural Experiment Station in 1914 that tillage materially affected the amount of precipitation absorbed by the soil. With a total precipitation of 9.56 inches, land in stubble absorbed 5 inches; disked stubble absorbed 6.25 inches; and stubble disked after harvest and fall plowed absorbed 7.25 inches.

Harris and Bracken (23), reporting in 1917 on the results of soil moisture studies under irrigation similar to those reported for dry farming at the Utah station, show that cultivation was more effective in conserving moisture than pulling weeds; the difference, however, was not great. The advisability of mulching with straw as compared with cultivation eight days after water is applied hinges on the question of labor. The difference in moisture content of the soil mulched with 2 inches of straw and soil cultivated 2 inches deep was 1 percent, and between cultivating 2 inches deep and no cultivation but with weeds pulled, was 1 percent.

Hutcheson, Hodgson, and Wolfe (25) as a result of corn cultivation experiments at Virginia Agricultural Experiment Station, 1913–1916, concluded that cultivation of corn is advantageous. Table 12 presents their average results.

TABLE 12.—*Average yields of grain and fodder obtained from different methods of cultivating corn at the Virginia station in the five years from 1913 to 1916, inclusive.*

No cultivation, weeds growing.		No cultivation, weeds cut with hoe.		Three cultivations.		Five cultivations.	
Grain, bu.	Fodder, tons.	Grain, bu.	Fodder, tons.	Grain, bu.	Fodder, tons.	Grain, bu.	Fodder, tons.
8.4	0.7	49.0	1.4	59.4	1.6	58.6	1.5

Call and Sewell (4), as a result of three years' studies with soil mulches, showed in 1917 that for silt loam types of soil with Kansas conditions, the maintenance of a soil mulch had practically no effect in reducing evaporation. It was also found that nitrate development was as extensive without cultivation as with cultivation. Later results (5), 1918, showed that cultivation by preventing weed growth conserved the soil's supply of available plant food, and that too much emphasis had been placed on tillage as related to moisture conservation and the development of plant food.

At the Kansas station, data regarding the effect of tillage on corn yields are available for the five years from 1914 to 1918, inclusive. These results are presented in Table 13.

TABLE 13.—*Annual and average yields of corn variously cultivated at the Kansas Agricultural Experiment Station during the five years from 1914 to 1918, inclusive.*

Cultivation treatment.	Yield per acre. 1914.	1915[a]	1916[b].	1917[c].	1918[d].	Average, 1914–17.
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Lbs.*	*Bu.*
Ordinary	13.0	65.0	43.9	39.6	8,457	40.4
Ordinary and 1-horse cultivator to maintain mulch	13.4	62.0	43.3	39.5	8,000	39.5
Ordinary and 1-horse cultivator every 10 days	11.0	58.8	43.4	39.6	8,850	38.2
Not cultivated; weeds hoed by hand	9.2	65.0	45.2	35.0	7,580	38.6

[a] Average yield upland and bottom land, fall plowed.
[b] Average yield, fall plowed, spring plowed, and disked.
[c] Average yield, fall plowed and unplowed land.
[d] Silage yields in pounds. No grain yield in 1918.

As an average of the four years, 1914–17, the uncultivated plots where the weeds were removed produced practically as great yields as the cultivated plots. Apparently there was not any advantage from the point of yield in cultivating corn, except for the purpose of killing weeds. The small differences in yield are considered within the experimental error.

These various citations on intertillage and cultivation, with the exception of the writings of Grandeau (22) and Kraus (31) and the results at the Virginia Agricultural Experiment Station (25), show but little if any differences in the effect of cultivated and uncultivated treatments in regard to yields, conservation of moisture, and nitrification.

SOIL AERATION AND NITRIFICATION.

Concerning the viewpoint that it is necessary to promote oxidation in various chemical changes and furnish sufficient oxygen for bacterial activity, while it is recognized that oxygen is essential for chemical and bacterial changes in the soil, soils with natural drainage and in climates of medium or well distributed precipitation may be of such a type texturally that they have sufficient aeration without cultivation practised for that particular purpose. Citations of experimental work proving this supposition have already been reviewed (5), but may with advantage be repeated in this article on tillage.

In 1902, King and Whitson (29) presented investigations at Wisconsin on the effect of increasing aeration on nitrification. They bored holes in the soil and determined nitric nitrogen in the surrounding area. The data obtained did not indicate that nitrification was increased by this manner of aerating the soil.

In 1906, Day (12) attempted to determine experimentally the effect of artificial aeration of soils at the Ontario Agricultural College for wheat, barley, oats, and peas. The plants were grown in crocks in duplicate. Air was forced through the soil of one set once a day. There was not a benefit from the aeration of any of the crops except peas, which were very much benefited the first year. The effect of aeration on the peas was not as great the second year

Russell and Appleyard (48), in 1915, reported results in England showing but little variation in the composition of atmospheric and soil air.

Leather (34) found that in the soils of India the diffusion of gases through soils at a depth of 12 to 15 inches is so efficient as to warrant the conclusion that cultivation of the surface soil is unnecessary for purposes of aeration. His investigations showed that even during the wettest weather, the volume of gas falls only to 15 to 20 percent of the soil volume or about half that which is present during long periods of hot, dry weather.

Gainey and Metzler (17) of the Kansas Agricultural Experiment Station, in 1916, from laboratory studies of the rate of nitrification in a compacted and an uncompacted soil, found greater nitrification on the compacted soil up to the point where the moisture content reached two-thirds saturation.

We may judge from these various reports on aeration of the soil that many soils naturally have sufficient aeration for optimum bacterial and chemical activity without cultivation.

GENERAL SUMMARY.

In general, we may conclude that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental evidence.

The review of tillage literature leads to the following conclusions:

(1) Plowing deeper than 7 inches has not generally resulted in an increase of crop yields.

(2) Shallow plowing may produce as great yields as deeper plowing, but the depth less than 7 inches which is best for economic production has not been determined.

(3) The question of frequency of plowing has not been answered, but it seems possible by proper rotation of crops to lessen the number of plowings.

(4) Cultivation may be necessary only to kill weeds and keep the soil in a receptive condition to absorb rainfall. Thus it is practical, except on very heavy soils, to reduce the amount of cultivation where the guiding policy is that of thoro cultivation in order to maintain a soil mulch.

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CONTROLLING FLAX WILT BY SEED SELECTION.[1]

E. C. Stakman, H. K. Hayes, Olaf S. Aamodt, and J. G. Leach.

Introduction.

Statistics of the United States Department of Agriculture[2] show that the principal area of flax production has in the last half century moved steadily westward from Kentucky and Ohio to the present area including Minnesota, North Dakota, South Dakota, and Montana. These figures show also that the annual production of flaxseed in this country is steadily declining. The average yearly production for the years from 1900 to 1909 inclusive was 25,966,700 bushels. For the next seven years, from 1910 to 1916 inclusive, the average production was only 17,155,571 bushels. In Minnesota the average yearly production from 1902 to 1909 was 5,322,000 bushels, while from 1910 to 1917 the yearly average was only 3,051,125 bushels. The conditions were similar in Iowa, North Dakota and South Dakota.

Since flax does not compete with weeds as well as some other crops do, new land is especially desirable for flax production. This would, in a measure, account for the above facts. It is very reasonable to suppose, however, that flax wilt is at least of equal or even of greater importance in causing this decrease in yield as well as the migratory movement of the crop. It is well known that when flax is grown for a number of successive years on the same soil, this soil becomes so heavily infected with the fungus causing flax wilt (*Fusarium lini* Bolley) that a profitable crop cannot be grown. Soil in this condition is usually spoken of as being "flax-sick." It is easy to conceive the effect this would have on the total flax production, directly by reducing the yield and indirectly by discouraging its culture. The gradual movement of the center of production to new lands is a natural sequence.

THE ROLE OF SELECTION IN CONTROLLING WILT DISEASES.

Bolley (1, 2)[3] first discovered the true nature of flax wilt and devised methods for its control. Crop rotation and seed treatment were

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[2] U. S. Dept. Agr. Yearbooks.

[3] Reference is to "Literature cited," p. 298.

found helpful, but the most promising control measure appeared to be the use of wilt-resistant seed. Bolley (3, p. 177) states that a few straggly plants survived the first year when varieties were grown on flax-sick soil. These were selected and the progeny were somewhat resistant the following year. After several years of selection, sorts were produced which yielded well on flax-sick soil. It is interesting to note that similar methods failed when applied to developing rust-resistant wheats. The difference in behavior of these two crops and the biological cause of development of resistant flax sorts by continuous selection are unanswered questions.

Methods similar to those mentioned above have been successfully applied by various workers to the control of wilt diseases of several crops. Orton (6, 7) succeeded in reducing losses from the wilt disease of cotton caused by *Fusarium tracheiphilum*, by selecting seed from individual resistant cotton plants which survived in heavily infected fields. This work resulted in the production of several wilt-resistant varieties of commercial value. These are being grown with success in wilt-infested areas of the south.

Jones and Gilman (5) employed the same methods in combating cabbage yellows, caused by *Fusarium conglutinana*.

The fusarium wilt of tomato (*Fusarium lycopersici*) has been successfully overcome by Essary (4). The same general plan was followed, resulting in the development of sorts possessing a high degree of resistance as well as other desirable characters.

Selection of wilt-resistant varieties, then, should offer a practical solution of the flax-wilt problem. The figures cited above show, however, that flax production is decreasing, and they strongly indicate that it will continue to decrease unless some effective method of control is put into general practice. The problem now is to produce wilt-resistant varieties of flax of good yielding ability and to bring them into general cultivation. It is the belief of the writers that sufficient attention has not been given by pathologists and agronomists to the production and distribution of resistant varieties of flax.

Little confirmatory evidence of Bolley's remarkable work in developing wilt-resistant flax has ever been published. The writers are of the opinion that the problem is sufficiently important and the methods so well tried as to make the publication of supplementary data valuable. This paper summarizes the result of four years of selection of flax for wilt resistance. This work was done with the object of determining the efficiency of the method and to call attention to a simple plan adapted to the use of plant breeders, agronomists, and intelligent farmers.

METHODS AND MATERIALS.

Preliminary work was begun by the senior author in 1911. In 1914 several varieties and selections of flax, obtained from the Division of Agronomy and Farm Management of the Minnesota Agricultural Experiment Station, were sown on flax-sick soil. In order to insure a heavily infected disease plot the soil was sprayed at intervals with a water suspension of spores of *Fusarium lini*. Very good results were obtained in this way. All of the varieties planted proved to be very susceptible, from 50 to 100 percent of the plants being killed by wilt. Pure cultures of *Fusarium lini* were obtained from the diseased plants.

Seed selected in bulk from the surviving plants were planted again in 1915 on the same soil. Seed from the original nonselected varieties were planted as checks. It was not found necessary to spray the soil with the spore suspension after the first year, since the soil remained heavily infected and in fact became more heavily infected the second year. This was shown by the fact that practically 100 percent of the check plants were killed by wilt in 1915. Bulk and individual plant selections were made in 1915 and 1916. Bulk selections only were made in 1917. These selections were sown each year on the same soil, nonselected varieties being planted as checks.

RESULTS OF SELECTION.

Table 1 shows the results of the four years of selection. It will be noticed that in most cases a high degree of resistance was obtained by selection while from 75 to 100 percent of the nonselected plants proved to be susceptible each year. It will also be seen that the degree of resistance developed by selection was by no means always consistent. Selections from some varieties produced a high percentage of resistant plants after having been selected only once; the degree of resistance of others apparently increased with each successive selection. Some showed increased resistance after one selection, but in the following year seemed to lose all that had been gained. In a few cases there was no appreciable increase of resistance. It should be noted, however, that with the small amount of seed planted, especially in the case of individual selections, there is great chance for variation. For this reason, when drawing conclusions as to the mechanism involved in the production of wilt resistance, very little importance should be attached to these figures. More extensive work is necessary before the question of the mechanism involved can be answered The essential fact is that a high degree of resistance actually can be obtained.

TABLE 1.—*Results of four years' selection of flax for wilt resistance.*

Minn. Accession No.	Name.	1914.		1915.		1916		1917.		1918.	
		Percent wilt.	Type of selection.[a]	Percent wilt.	Type of selection	Percent wilt.	Type of selection.	Percent wilt.	Type of selection.	Percent wilt.	Type of selection.
Class I[b]											
25	Blue Dutch.	95	Nonselect	35	Bulk	22	Bulk	0	Bulk	5	Bulk
67	Russian, Dept. No. 9926	85	do.	40	do.	27	do.	0	do.	5	do.
77	Russian, Dept. No 9967	80	do.	60	do.	60	do.	0	do.	Discarded	
78	Russian, Dept. No. 9969	90	do.	15	do.	44	do.	0	do.	10	do.
100	Improved Riga	75	do.	60	do.	87	do.	0	do.	Discarded	
105	North Dakota	50	do.	5	do.	59	do.	0	do.	10	do.
Class II											
25-1	Blue Dutch.	95	do.	35	do.	22	do	0	Individual	5	do.
67	Russian, Dept. No. 9926	85	do.	40	do	27	do.	80	do.	Discarded	
74-1	Russian, Dept. No. 9962	50	do.	10	do.	38	do.	0	do.	15	do.
77	Russian, Dept. No. 9967	80	do.	60	do.	60	do	80	do.	Discarded	
91-1	Russian, Dept. No. 10006.	70	do.	15	do.	63	do.	0	do.	2	do.
100-1	Improved Riga	75	do.	60	do.	87	do	0	do.	5	do
19	Improved Belgium			99	Nonselect	94	do.	17	do.	Discarded	
174	N. Dak. Resistant 73.			99	do	100	do.	Discarded			
Class III											
175-1	N. Dak. 1221			99	do.	94	do.	0	do.	2	do.
173	N. Dak. Resistant 52.			40	do.	97	do.	60	Bulk	Discarded	
173-1	do.			40	do.	76	Individual	75	Individual	do.	
Class IV											
25-7	Blue Dutch.	95	do.	30	Bulk	10	do.	0	Bulk	2	do.
25-8	do.	95	do.	30	do.	1	do.	0	do.	2	do.

[a] Type of selection refers to the method of selecting plants the previous year.

[b] Class 1 includes plants produced by bulk selection for four years, 1914 to 1917, inclusive.

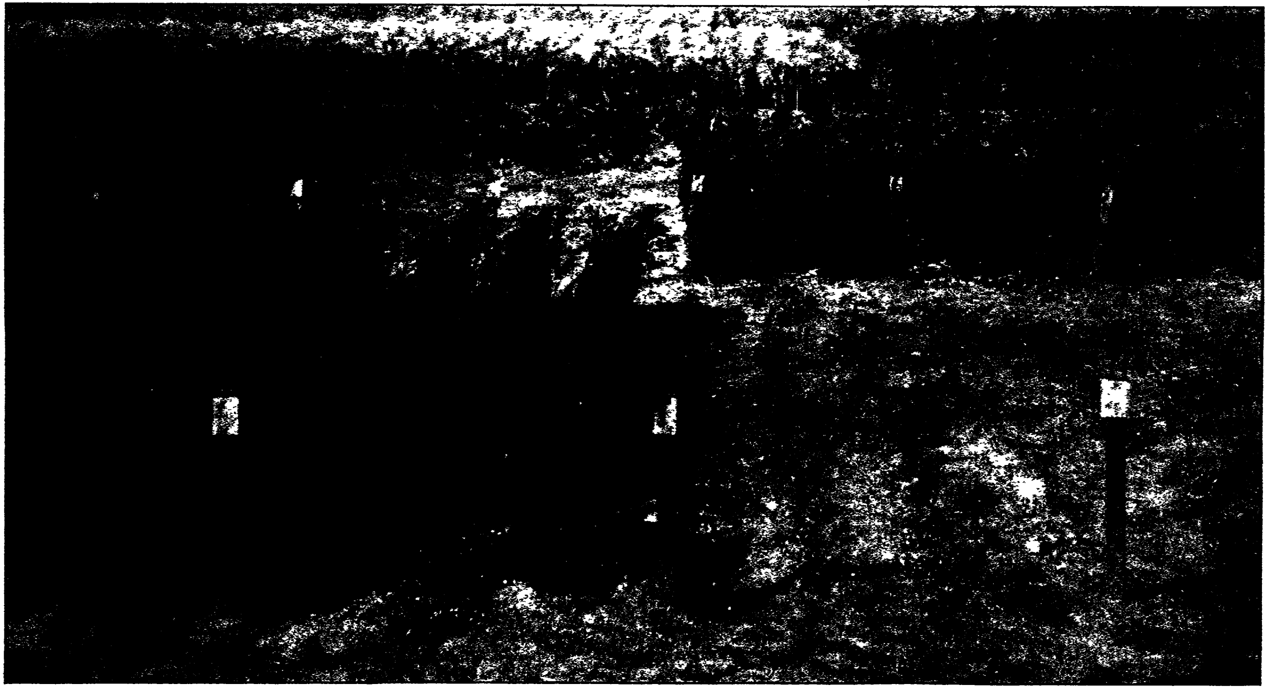
Class 2 includes plants produced by bulk selection for three years, 1914 to 1916, inclusive, and individual selection in 1917.

Class 3 includes plants produced by bulk selection for two years, 1915 to 1916, inclusive, and individual selection in 1917.

Class 4 includes plants produced by bulk selection in 1915 and individual selection in 1917.

Class 5 includes plants produced by bulk selection in 1914 and 1915 and individual selection in 1916 and 1917.

Class 6 includes nonselected seed. Only bulk selections were made in 1918.



Selected and non-selected flax on wilt-sick soil.

Right foreground, non-selected flax killed by wilt; left foreground, selected flax; left background, non-selected; right background, selected.

TABLE 1.—*Results of four years' selection of flax for wilt resistance.*—Concluded.

Minn. Accession No.	Name.	1914.		1915.		1916.		1917.		1918.	
		Percent wilt.	Type of selection[a].	Percent wilt.	Type of selection.	Percent wilt	Type of selection.	Percent wilt.	Type of selection.	Percent wilt	Type of selection.
74-1	Russian, Dept. No. 9926	50	Nonselect	10	Bulk	2	Individual	0	Bulk	2	Bulk
74-2	do.	50	do.	10	do.	7	do.	0	do.	5	do.
78-2	Russian, Dept. No. 9969	90	do.	15	do.	14	do.	0	do.	50	do.
78-5	do.	90	do.	15	do.	9	do.	0	do.	50	do.
78-6	do.	90	do.	15	do.	19	do.	50	do.	Discarded	
79-1	Russian, Dept. No. 9973	50	do.	20	do.	4	do.	25	do.	do.	
Class V											
25-7-2	Blue Dutch.	95	do.	30	do.	10	do.	50	Individual	do.	
25-8-2	do.	95	do.	30	do.	1	do.	6	do.	20	do.
74-1-2	Russian, Dept. No. 9962	50	do.	10	do.	2	do.	0	do.	20	do.
74-2-2	do.	50	do	10	do	7	do.	0	do.	20	do.
74-4-2	do.	50	do.	10	do.	8	do.	0	do.	20	do.
78-1-2	Russian, Dept. No 9969	90	do.	15	do.	28	do.	0	do.	30	do.
78-2-2	do.	90	do.	15	do.	14	do.	50	do.	Discarded	
78-5-2	do.	90	do.	15	do.	9	do.	40	do.	do.	
78-6-2	do.	90	do.	15	do.	19	do.	50	do	do.	
79-1-2	Russian, Dept. No. 9973	50	do	20	do.	4	do.	40	do.	do.	
Class VI											
25	Blue Dutch			30	Nonselect	92	Nonselect	75	Nonselect	98	Nonselect
67	Russian, Dept. No. 9926									100	do.
74	Russian, Dept. No. 9962									100	do.
78	Russian, Dept. No. 9969									100	do.
100	Improved Riga									99	do.
105	Nursery selection							85	do.	98	do.
173	N. Dak Resistant No. 152			40	do.	94	do.	70	do.		
174	N. Dak. Resistant No 73			99	do.	97	do.	75	do.	100	do.
175	N. Dak. Resistant No. 1221			100	do.	94	do.	100	do.	100	do.
176	N. Dak. Resistant No 1133			100	do.						
177	N. Dak. Resistant No. 155			100	do.						

In 1918 it was thought desirable to test more accurately and on a more extensive scale the real value of the resistant selections. Accordingly all the poorer selections were discarded and all available seed of the most promising sorts were used to make an extensive yield test. The test was made at two places, at the University Farm, St. Paul, Minn., and at Waseca, Minn. The selections were sown on flax-sick soil in 3-row plats, each plat being replicated two times. In computing the yields all three rows of each plat were considered. Ten-foot rows were planted at St. Paul and thirty-foot rows at Waseca. Table 2 shows the results of these tests.

TABLE 2.—*Yield in bushels per acre of selected and nonselected flax on "flax-sick" soil in 1918.*

Selection No.	St Paul.					Waseca.					Average St Paul and Waseca.
	Percent wilt at maturity.	Ser. I.	Ser. II.	Ser. III.	Average.	Percent wilt when two weeks old.	Ser. I.	Ser. II.	Ser. III.	Average.	
Class I	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
25	5	6.34	8.23	12.00	8.86	0	16.86	13.20	11.60	13.88	11 37
67	5	5.65	4.45	5 83	5.16	0	12.11	9.83	4 40	8 78	6.97
78	10	3.42	3.42	2.57	3.14	5	9.88	8.80	4 51	7 73	5.43
105	10	5.48	5.14	2.74	4.45	0	13.71	11.31	6.17	10 39	7.42
Class II											
(16) 25 1	5	7.03	1.71	9.08	8.06	0	14 91			11 43	9.74
(16) 74–1	15	4 97	.68	7.54	6.26	0	12 80			9.81	8 03
(16) 91 1	2	13.20	13.37	3.61	10 06	0	16 63			12.76	11.41
(16) 100–1	5	5 83	5.31	3.42	4.85	0	17.71			13.58	9.16
Class III											
(16) 175–1	2	16.19	9.94	12.34	12 82	0	20.00	16.97		15.86	14.34
Class IV											
(15) 25–7	2	9.60	5.14	9.60	8.11	0	15.54	10.91	8.05	11.50	9.80
(15) 25–8	2	10.63	6.34	7.71	8.23	0	15 60	10.57	6.46	10.87	9.55
(15) 74–1	2	12.17	8 91	10.48	10.52	0	13.88	8 91	6.11	9.60	10.06
(15) 74-2	5	10.28	10.11	7 03	9.14	0	11.14	9 31		10.22	9 68
(15) 78–2	50	3.08	2.40	4.11	3.20	10	10.11	8.51	6.74	8.45	5.82
(15) 78 5	50	2.57	8.40	1.20	2.86	10	10.34	8 97	8.74	9.35	6.10
Class V											
(15) 25–8–2	20	7.37	8.05	11.14	8.85	0	13.43			10.30	9.57
(15) 74–1–2	20	7.03	7.37	12.34	8.91	5	11.94			9.16	9.03
(15) 74-2 2	20	6.00	5.14	10.80	7.81	5	11.60			8.89	8.30
(15) 74-4–2	20	6.51	9.77	10.97	9.08	5	11.03			8.46	8.77
(15) 78–1-2	30	15.14	12.51	10.11	9.25	5	12.11			9.29	9.27
Class VI											
25	98	1 —	1 —	1 —	1 —	75	1.65	2.00	3.42	2.35	
67	100	0	0	0	0	95	.28	.28	.51	.35	
74	100	0	0	0	0	80	1.02	2.34	3.31	2.22	
78	100	0	0	0	0	90	.17	.51	.80	.51	
100	99	1 —	1 —	1 —	1 —	50	1.48	1.88	5.43	2.93	
105	98	1 —	1 —	1 —	1 —	50	2.85	2.62	6.51	4.01	
174	100	0	0	0	0	95	.22	.34	1.48	.68	
175	100	0	0	0	0	99	0	.22	2.51	.91	

Certain general facts are apparent from a study of these results. The most important fact brought out is that the selections which were most resistant at University Farm behaved in the same manner at the Waseca substation. This is important because it has been shown that varieties of plants resistant to certain diseases in a given locality are not always resistant in others, due to the presence of a different strain of the pathogene. It is of interest to note in Table 1 that the two selections listed at North Dakota Resistant No. 13 and North Dakota Resistant No. 52 were very susceptible at the University Farm. These varieties had been grown several years since their original distribution so it is possible that they were somewhat mixed. It is possible also that a variety retains its resistance only when grown continuously in the presence of the disease-producing organism. More extensive studies are being made to determine this and also to determine the possible occurrence of different strains of the fungus. It is apparent, however, that the same strain of *Fusarium lini* is present at both Waseca and University Farm, Minn.

It will no doubt be noticed that in series I to III at Waseca there was a progressive decrease in yield. This was undoubtedly due to the poorer soil on this side of the field. In some cases there was not enough seed available for more than one or two series. In the final averages the yields for these selections are recomputed on the basis of the average decrease in the selections which were grown in all three replications. The results as given indicate that this method of computation is fairly reliable.

That actual results have been obtained is readily seen by comparing the average yields of the selected varieties with those of the nonselected varieties. The differences in wilt resistance are shown in Plate 9.

It is quite apparent that, although good results can be obtained by the bulk method of selection, the individual plant method gives a more uniform product.

SEED PLOT METHOD FOR PRACTICAL PURPOSES.

It is evident that by careful selection it is possible to produce a good crop of flax on heavily infected flax-sick soil. The question is, how can this fact be best utilized in practice. The production and use of wilt-resistant varieties of flax should be brought into general practice as soon as possible unless the production of flaxseed is to decrease continually. The first essential of any crop improvement system is that it be as simple as possible. With this in view a seed-plat method

is recommended for the use of the flax producer. The highest yielding selections already produced should be increased and distributed to farmers as has already been done in North Dakota. The seed for field use can then be grown on a small plat of soil known to be infested with wilt. This plat of flax-sick soil may then constitute a permanent seed plot. Sufficient seed should be saved from the seed plat each year to plant the following year, the remaining seed being sown in the general field. It is believed that if this plan were extensively adopted the losses from flax wilt could very largely be eliminated and flax production eventually could be restored to normal.

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EXPERIMENTS IN SPACING COTTON.[1]

O. F. Cook.

Knowledge of the structure and habits of a plant is essential to a full understanding of cultural requirements. It is not sufficient to perform experiments, or to give directions. Established opinions and customs are not changed until the underlying facts and relations are brought clearly before the mind. A theory may become dominant like that of wide spacing of cotton, even without facts to support it. Belief governs action in agriculture no less than in other fields of human effort. New facts or principles are not fully applied until they are generally and thoroly understood, and the previous opinions are seen to have been defective.

General reasoning that may be applicable to other crops is distinctly out of place with cotton, because the plant has habits of its own. There is no direct or regular relation between the size of cotton plants and the yield of lint and seed, but very often a contrary or inverse relation, smaller harvests from larger plants. The key to this paradox is that the main stalk of the cotton plant produces two distinct kinds of branches, one kind able to bear an early crop of bolls, the other not. If growth is too luxuriant at first vegetative branches are developed at the expense of fruiting branches.

Rank growth of young cotton plants also leads to blasting and shedding of floral buds or young bolls, and even to general abortion of the early fruiting branches, in cases where young plants that have behaved normally in the first weeks pass into a very luxuriant condition, in warmer weather. The physiological state of plants making rapid vegetative growth not only is unfavorable to the setting of fruit but apparently involves injury and death of the fruiting parts, even when other unfavorable conditions are not encountered.

Chances of an early crop are much better with plants of moderate, restricted growth and only a central or main stalk, than with the large plants that develop numerous vegetative branches or side stalks. Plants that produce only a single stalk not only are in a better physiological state for producing and retaining floral buds and young bolls

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication May 5, 1919.

early in the season, but cultural conditions in single-stalk fields are also more favorable for bringing the early bolls to maturity. Injurious crowding is avoided by suppressing the side stalks, altho the plants are more numerous and stand closer together in the rows. The rather narrow, upright form of the single-stalk plants permits the space between the rows to remain open, so that the lower fruiting branches continue to be reached by the light and heat of the sun. When the plants grow large and have strong vegetative branches that fill the space between the rows, the lower fruiting branches are thrown into deep shade and most of the early bolls are aborted.

Vegetative branches not so large or so numerous as to interfere directly with the development of early bolls may still be injurious indirectly. Overgrown plants are more likely to be checked by drouth, which is another cause of blasting and shedding of buds or young bolls. In some experiments large spreading plants were conspicuously wilted in the middle of the day, while small plants in adjacent rows remained turgid. Such differences of behavior explain the cultural superiority of single-stalk plants, and the advantage of suppressing or avoiding the development of the vegetative branches. Usually this can be accomplished by the simple expedient of leaving the plants closer together in the rows, and thinning them later than was formerly considered advisable. The system of controlling the vegetative branches has been described as single-stalk cotton culture.[2]

The experiments that have been made under a very wide range of conditions in different parts of the cotton belt leave no doubt that the principle of control of branching can be used to general advantage, but no uniform directions can be given that would insure the best results under all conditions. To expect this would be as reasonable as prescribing universal methods for other farm operations. As already explained, the single-stalk system is flexible and readily

[2] For more detailed accounts of structural and cultural features see publications of the U. S. Department of Agriculture, especially the following: Dimorphic Branches of Tropical Crop Plants, Bur. Plant Indus. Bul. 198; Arrangement of Parts in the Cotton Plant, Bur. Plant Indus. Bul. 222; the Branching Habits of Egyptian Cotton, Bur. Plant Indus. Bul. 249; Morphology of Cotton Branches, Bur. Plant Indus. Cir. 109; A New System of Cotton Culture, Bur. Plant Indus. Cir. 115; Abortion of Fruiting Branches in Cotton, Bur. Plant Indus. Cir. 118; A New System of Cotton Culture and Its Application, Farmers' Bulletin 601; Single-Stalk Cotton Culture, Bur. Plant Indus. Doc. 1130; Brachysm a Hereditary Deformity of Cotton and Other Plants, Jour. Agr. Research, 3: 387; Single-Stalk Cotton Culture at San Antonio, Texas, Dept. Bul. 279; Experiments with Single-Stalk Cotton Culture in Louisiana, Arkansas and North Carolina, Dept. Bul. 526.

adapted to circumstances. Bad weather, lack of labor or other obstacles may interfere with thinning at an ideal time, but whenever the work is done the principle of control needs to be taken into account.

Practical familiarity can be gained by simple comparisons of 12-inch and 6-inch spacings in alternate blocks of 4 or 5 rows, with both spacings thinned at the same time, preferably when the plants are from 6 to 10 inches tall. The number and size of the vegetative branches developed in the 12-inch spacing will serve as a measure of luxuriance for the local conditions, while the 6-inch rows will show more restriction and control. If vegetative branches are not developed in the 12-inch spacing, it will be evident that thinning was deferred much longer than was necessary to suppress vegetative branches in the 6-inch rows, and that earlier thinning might have increased the yields of these rows. It is only in extreme conditions, as on plants forced into rapid growth after being checked severely by cold or dry weather, that large vegetative branches develop in 6-inch spacings, unless the stands are irregular. Loss of the terminal bud often results in the development of several vegetative branches, but if thinning is not done too early the injured plants are easily recognized and removed.

Thick stands require earlier thinning, while open stands sometimes yield better without thinning. Cotton of moderate growth may be thinned earlier than rank-growing cotton, but very early thinning, before the plants are 5 or 6 inches high, exposes the seedlings prematurely, and often injures the crop by reducing the stand or by increasing the number of plants crippled by leafcut or injured by insects. Late planted cotton usually needs to be left closer to the rows and thinned at a more advanced stage of growth than early plantings, often not until the plants are 10 or 12 inches high, or even 15 or 18 inches, depending upon the stand and other conditions of growth. Another general relation is that of time of thinning to the spacing that should be used. If the spacing is to be close there is less need to defer thinning, but if thinning is much deferred it becomes more necessary to use close spacing. Otherwise the yield may be seriously reduced, especially under short-season conditions.

By planting in hills and thinning gradually, plants usually can be kept in the single-stalk form at any distance apart, 1 foot, 2 feet, or 3 feet, but closer spacings are preferable. Not how many feet, but how many inches apart the plants should be is the practical question to be determined by local experiments. Fortunately such experiments are not difficult, and can be tried in ordinary fields of cotton, with changes only in thinning and spacing.

In single-stalk culture of Egyptian cotton under long-season conditions in Arizona a wide range of spacings can be used, any of them better than uncontrolled branching. Yields of over a bale per acre have been obtained from single-stalk plants 2 feet apart in the rows, and also from plants only 4 inches apart, as well as from several intermediate spacings, 6 inches, 8 inches, 12 inches, and 18 inches, but usually with distinct advantages for the closer spacings, when comparisons are made in adjoining plots. Even with rows only 2.5 feet apart and the plants spaced at 4 inches in the rows, the yield was large. Rows 3.5 feet apart with plants 6 to 8 inches apart in the rows has been the most successful arrangement used thus far on a large scale, but in the more luxuriant fields the rows meet across the lanes and many of the lower fruiting branches are smothered. For conditions of rank growth experiments are now to be made with rows 4 feet apart and plants 4 inches apart, as an arrangement likely to give somewhat more effective control of growth and branching in the early stages, and less crowding between the rows.

Wide spacing and early thinning continue to be tried by farmers who have not had experience with Egyptian cotton under the Arizona conditions, but crowding is only made worse when the branching is not controlled. Fields of overgrown plants become veritable jungles of dense foliage and heavy wood limbs, with low yields of fiber, not of the best quality and difficult to pick. Thinning first to 4 inches will allow more space to be given later in the season, after the stage of producing vegetative branches is past, by pulling out every second or third plant, if experiments prove that sufficient advantage can be gained to justify the additional labor. With ordinary stands thinning to 4 inches may be done when the plants are from 6 to 10 inches tall, and further thinning at any later stage, when it appears that the plants are becoming crowded to an extent that is likely to reduce the yield or impair the quality of the fiber.

With upland cotton in Texas there may not appear to be the same need of controlling the growth of the plants by cultural means, since growth is often restricted by cold or dry weather, but it is essential that bolls be set and retained early in the season since drouths or boll weevils usually interfere with the production of a late crop. The period of setting bolls may be very short, as in the experiments described by Rowland M. Meade in 1914 at San Antonio, Texas, when nearly all of the bolls were set within about 25 days. In this case more than twice as much cotton was produced from small single-stalk plants standing only 6 to 8 inches apart in the rows than from large

spreading plants thinned early to 2 feet apart that developed large vegetative branches. Tho results would not differ so widely in longer fruiting seasons, there is no reason to expect in any year that more cotton per acre can be produced on large spreading plants. Differences of 20 to 50 percent in yield are not infrequent, and afford sufficiently striking examples of the utility of branch control.

Earliness, in the practical sense of increased production in shorter fruiting periods, cannot be determined from first dates of flowering or of opening of bolls, but is shown by the setting of more bolls and the maturing of a larger crop. Nevertheless, any differences of behavior that can be observed and recorded are likely to be of interest or of practical use in tracing effects back to their causes and thus learning how the principle of control may be applied to the best advantage. Features that can be used for such comparisons are the size or rate of growth of the main stalks, the numbers, lengths, and positions of the two kinds of branches, the dates and rates of flowering and opening of bolls, numbers of bolls with 3, 4 or 5 locks, and weights of seed cotton from the different classes of bolls, in addition to the lint and seed characters which usually receive attention.

Control of branching may be considered successful when comparisons show practical advantages in larger yields or earlier ripening of the crop, but this does not prove that the full possibilities of the system have been realized in any particular test. That partial control or over-control may be better than no control, only shows that it is desirable to go further and determine the most effective utilization of the principle, thru local experiments and comparisons of behavior. It is only in this way that adequate discrimination and skill can be developed in the handling of different varieties and types of cotton under the wide range of cultural and seasonal conditions that are encountered in practice.

EFFECT OF WOUNDS ON LOSS OF WEIGHT OF POTATOES.[1]

O. BUTLER.

We are always told that in harvesting potatoes care should be exercised not to cut or bruise them unnecessarily, as not only is their market value much reduced when they are roughly handled but they also lose weight more rapidly than uninjured tubers. This latter effect of rough handling has not been particularly stressed to my knowledge, but, as the following experiment shows, it is nevertheless worthy of attention.

Tubers of Triumph, Early Rose, and Rural New Yorker potatoes were carefully selected for freedom from wounds and bruises and divided into two equal series, which were respectively denoted by the letters A and B. In series A a small slice, hardly more than skin deep, was cut off each tuber; while in series B the tubers were not damaged in any way and thus served as a measure of the loss due to slight wounding. The temperature of storage was 8° to 10° C. and the experiment was allowed to run 111 days. The results obtained are presented in Table 1.

TABLE 1.—*Effect of wounding on loss of weight of potatoes.*

Variety and method of treatment.	Loss of weight after—									
	8 days.	16 days	23 days.	32 days.	40 days.	48 days.	66 days.	79 days.	95 days.	111 days.
	Per-cent.	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*
Triumph:										
Tubers not cut	0.48	1.03	1.45	1.92	2 30	2.75	3.87	5.22	7.12	9.21
Tubers cut	1.57	2 19	2.65	3 22	3 65	4.11	5.45	7.11	8.94	11.81
Early Rose:										
Tubers not cut	0.56	1.08	1.52	1.97	2.39	2.62	3.36	4.21	5.10	6.23
Tubers cut	1.30	2.25	2.73	3.37	3.90	4.30	5.36	6.27	7.54	9.08
Rural New Yorker:										
Tubers not cut	0.72	1.13	1 67	2.22	2.72	3.17	4.07	4.98	6.25	7.30
Tubers cut	1.61	2.49	3.02	3.72	4.42	4.67	5.70	7.06	8.20	9.61

As will be seen from a consideration of Table 1, the loss of weight due to wounding, while rapid during the first week, at first markedly and then slowly decreases thereafter. The increased loss of weight

[1] Contribution from the New Hampshire Agricultural Experiment Station, Durham, N. H. Received for publication June 23, 1919.

due to the wounding does not become extinct, however, until after 79 days, when the ratio between loss of weight of non-cut and cut tubers assumes a constant value.

The complete healing of a wound and the return of the potato to a normal condition is rather a slow process at a storage temperature of 8° to 10° C. and one would expect that storing wounded potatoes at a temperature more suitable for rapid healing would cause the ratio between loss of weight from cut and non-cut tubers to assume a constant value much more promptly. In effect as may be gathered from Table 2, healing occurs promptly at 20° C. and loss of weight is relatively less important.

TABLE 2.—*Effect of temperature on the rapidity of healing of wounded Triumph potatoes, the loss of weight of non-cut tubers being taken as unity.*

Temperature of storage.	Duration of experiment.							
	8 days.	16 days.	32 days.	40 days.	48 days.	4 days.	79 days.	95 days.
°C.								
20	1.92	1.49	1 41	1 24	1.25	1.16	1.24	1.31
8-10	3.27	2.12	1.67	1.58	1.49	1.40	1 36	1.25

Advantage cannot well be taken of this fact in practice, however, as the saving realized would amount to only a half percent as will be seen from the following figures, a duration of storage of 111 days being assumed.

	Percent. loss of weight.
Wounded potatoes stored at 20° C. for 32 days, then placed in storage at 8-10° C.	11.25
Wounded potatoes stored directly at 8-10° C.	11.81
Sound tubers stored at 8-10° C.	9.21

It is clear that if slight wounding occasions a loss of more than 2 percent, which is not in itself negligible, larger losses will follow rough handling. Potatoes should therefore be carefully harvested and care should be exercised neither to cut nor unnecessarily bruise them for, as we have seen, tubers are more sensitive to injuries than would be anticipated from their general solidity.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership of the Society reported in the May number was 537. Since that time 14 new members have been added and 10 have resigned, making a net gain of 4 and a present membership of 541. The names and addresses of the new members, the names of those who have resigned, and such changes of address as have been reported follow.

New Members.

Baldwin, J. L., Agr. Expt. Sta., Purdue Univ., La Fayette, Ind.
Bayles, John J., Experiment Farm, Coly, Kans
Ching, K. A., Agr. Expt. Sta., Honolulu, Hawaii.
Chung, H. L., Agr. Expt. Sta., Honolulu, Hawaii.
Davis, L. Vincent, 1248 S St., Athens, Ga.
Esplin, Alma, Cedar City, Utah.
Fortun, Gonzalo M., Calle g No. 5, Santiago de las Vegas, Cuba.
Gonzalez, Joaquin J., Apalit, Pampanga, Philippine Islands.
LeWorthy, G. E., School of Agriculture, Morrisville, N. Y.
Miller, Justus R., Dept Agr., Parliament Bldg., Toronto, Canada.
Moss, W. A., Experiment Farm, Felt, Idaho.
Nelson, A. L., Cheyenne Field Station, Cheyenne, Wyo.
Stone, Benj. C., 174 Second Ave., New York, N. Y.
White, C. L., Box 137, Clinton, Mo.

Members Resigned.

Allen, Edward R.,
Brewer, Herbert C.,
Curtis, H. P.,
Graber, L. F.,
Holt, L. V.,
Jensen, L. N.,
Roudebush, R. I.,
Paxton, Glen E.,
Stephenson, R. E.,
Van Alstine, E.

Changes of Address.

Bauer, F. C., 932 W. Johnson St., Madison, Wis.
Birchard, F. J., Postal Sta. B., Winnipeg, Man., Canada.
Burdick, R. T., College of Agriculture, Fort Collins, Colo.
Burgess, Paul S., College of Agriculture, Berkeley, Cal.
Carleton, M. A., Cosmos Club, Washington, D. C.
Chapman, James E., Box 84, Route 3, Anoka, Minn.
Clark, Chas. F., Presque Isle, Maine.
Clark, Chas. H., Albert Dickinson Co., Lock Drawer 788, Chicago, Ill.
Clemmer, H. J., Experiment Farm, Dalhart, Texas.
Fippin, E. O., Agr. Bureau, Lime Association, Mather Bldg., Washington, D. C.
Gillis, M C., R. F. D. 4, South Bend, Ind.

GRANOWSKY, ALEX., P. O. Box 272, Mancos, Colo.
GRIFFEE, FRED, Agronomy Div., University Farm, St. Paul, Minn.
HOWAT, JOHN, Huntsville, Mo.
KENNARD, F. L., Moscow, Idaho
KIDDER, A. F., Agr. Expt. Sta., Baton Rouge, La.
LATOURETTE, LYMAN D., 1324 East Fillmore St., Phoenix, Ariz.
LECLERC, J. A., Miner-Holland Milling Co, Wilkes-Barre, Pa.
LOVE, RUSSELL M., Brooklyn, Pa.
LUND, VIGGO, Maribo Sugar Factory, Maribo, Denmark.
NEWTON, R., College of Agriculture, Edmonton (So.), Alta., Canada.
PENDELFTON, ROBERT L., Asst. Dir. of Agriculture, Gwalior, India.
RILEY, J. A., Coast Experiment Station, Summerville, S. C.
SMITH, NELSON S, School of Agriculture, Vermilion, Alta., Canada.
SMITH, OLIVER, 6 Cedar Parkway, Chevy Chase, Md.
STEMPLE, F. W., Aurora, W. Va.
TUTTLE, H FOLEY, Room 1010, 111 W. Monroe St, Chicago, Ill.
WESTLEY, ROY O., Farm Crops Dept, Wash. State Col., Pullman, Wash.
WINTERS, N. E, Extension Agronomist, Charlotte, N. C
WOODARD, JOHN, Hull Laboratory, Univ of Chicago, Chicago, Ill.

NOTES AND NEWS.

R. P. Bean has been appointed superintendent of the newly established State irrigation substation at Prosser, Wash.

Guy Potter Benton, educational director of the American Army of Occupation in Germany, has resigned as president of the University of Vermont.

J. F. Block, formerly agricultural engineer with the irrigation branch, Department of the Interior, Calgary, Alta., is now assistant superintendent of the experiment station at Rosthern, Sask.

Chas. H. Clark, formerly in charge of flax seed investigations in the U. S. Department of Agriculture, resigned September 1 to accept a position with the Albert Dickinson Company, wholesale seed merchants, with headquarters in Chicago.

Thomas P. Cooper, director of the Kentucky station, has also been appointed director of extension, with T. R. Bryant and Geoffrey Morgan as assistants.

J. D. Eggleston, for the past several years president of the Virginia Polytechnic Institute, resigned July 1 to become president of Hampden-Sidney College. He was succeeded by Julian A. Burruss, formerly president of the State Normal School at Harrisonburg, Va.

The experimental work with fertilizers and forage crops formerly conducted at McNeill, Miss., with E. B. Ferris as assistant director in charge, has been transferred to Poplarville.

R. L. Hensel, of the Forest Service, has been appointed associate professor of pasture management in the Kansas station, where he will have charge of pasture investigations which are planned to make better use of the grass lands of the State.

E. A. Hodson, assistant professor of agronomy in the Delaware college, resigned June 30 to accept a position with the Arkansas station.

Jesse M. Jones, director of extension in Virginia, has resigned to take charge of the agricultural and industrial department of the Seaboard Air Line Railway, and has been succeeded by John R. Hutcheson, formerly assistant director of extension.

F. L. Kennard, county agent in Whitman Co., Wash., has resigned to engage in the seed business in Moscow, Idaho.

A. F. Kidder has resigned as professor of agriculture in the Louisiana college to become agronomist and assistant director of the Louisiana station at Baton Rouge.

F. G. Krauss, superintendent of the extension division in the Hawaii Federal station, has been placed in charge of the Haleakala homestead demonstration farm in addition to his other duties.

Forest W. McGinnis is now assistant professor of agronomy and assistant agronomist of the Minnesota college and station.

Wallace Macfarlane, formerly chemist of the Oklahoma station, is now in charge of soil fertility investigations in the divisions of agronomy and chemistry of the Hawaii Federal station.

H. A. Morgan has been appointed president of the University of Tennessee, effective July 1, in addition to his duties as dean and director. J. D. Hoskins, dean of the college of liberal arts, is assistant to the president; C. A. Willson, animal husbandman, is assistant dean of the college of agriculture; and C. A. Mooers, chemist and agrononiist, is assistant director of the station.

C. L. Newman has resigned as head of the department of agronomy of the North Carolina college and station to accept a position with the Federal Board of Vocational Education.

James R. Riggs, an Indiana farmer and business man, is now assistant secretary of the Federal Department of Agriculture.

George Severance, vice dean of the Washington college of agriculture, is head of the newly established department of farm management in that institution.

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SYNTHETIC PRODUCTION OF HIGH-PROTEIN CORN IN RELATION TO BREEDING.[1]

H. K. HAYES AND R. J. GARBER.

INTRODUCTION.

A standard plan of procedure has been developed for the small grain breeder by the application of Mendel's principles and thru studies in field plot technic. Minor variations in methods used by different investigators occur, but fundamental principles are well known.

With corn improvement there is no such uniformity of technic. Some breeders favor the use of the corn score card as a means of isolating higher yielding varieties (12).[2] A much larger number believe the score card is of no value in isolating higher yielding varieties (18, 23, 29). It is recognized that the corn shows promote an interest in crop production (13). However, this does not seem a good reason for teaching the corn grower that ear-type selection may be expected to increase yield. Many breeders believe that the ear-to-row test is very valuable and some workers believe it is the only method of isolating a higher yielding variety (20). Others doubt the value of ear-to-row breeding for farmers. They also question the value of its continued use by the investigator (18, 21, 23). Field experiments have not always been carefully planned. For example, some workers have made comparisons of varieties and strains by

[1] Published with the approval of the Director as Paper No. 178 of the Journal Series of the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn. Received for publication July 26, 1919.

[2] Reference is to "Literature cited," p. 317.

growing only a single row of each sort. Two errors are thus introduced, one due to competition between different varieties (19), the other to soil heterogeneity. This has led to the use of replicated plots each consisting of several rows.

A recent discussion of the reason for conflicting results of corn experiments is interesting. Carrier (1) has emphasized the immediate effect of foreign pollen on endosperm size and questions the reliability of varietal tests. This without doubt is one cause of error, for corn is largely cross pollinated (10, 28). There is certainly as much opportunity in plot studies for a variety to be pollinated with itself as with another variety. Thus, even tho yields are sometimes increased 5 to 10 percent due to the immediate effect of foreign pollen, it seems very doubtful if this would cause a difference in final yields of more than 2 percent in plot tests. There is another reason why a mixture of seed of varieties should on the average yield more than pure varieties (1). As seasonal conditions vary, a mixture of different sorts would contain some genotypes which were adapted for the season in question. The average of three years' data obtained at the Minnesota station indicates that mixtures are not always of great value. Two plots were used for each variety, each plot consisting of several rows. The respective average yields in bushels per acre of Minnesota No. 13, Minnesota No. 23, Mercer, and a mixture of equal quantities of seed of No. 13, No. 23 and Mercer are 46.1, 39.1, 44.5, and 46.3. Yields were computed after allowing the corn to become crib dry. It will be noted that the mixture yielded as much as the highest yielding variety, and gave an increase of nearly 7 percent over the average of the three varieties. Thus the method seems worthy of further trial.

The effects of inbreeding and crossbreeding on development go far toward explaining many of the conflicting results of corn studies. Selection modifies the genotypic nature of a variety. Artificial self-fertilization accomplishes a similar result in a much more rapid manner. The same fundamental principles, however, apply in both cases. The present paper is a discussion of inbreeding and crossbreeding in its relation to methods of corn improvement.

RESULTS OF SELF-FERTILIZATION IN CORN.

The results of self-fertilization (4, 5, 6, 15, 24, 25) in corn are well known and need be only briefly summarized. It is now recognized that self-fertilization is not in itself harmful. By continued self-fertilization strains are isolated which are homozygous for all or

nearly all of their characters. From a theoretical standpoint the first year of self-fertilization has the greatest effect and the strain gradually approaches the homozygous condition. Eight to ten years of continuous self-fertilization should be sufficient to produce strains which are homozygous for all or nearly all characters. Since only single plants are used as parents for each generation, it is theoretically possible for many years to elapse before homozygosity is reached. It is equally possible to produce a homozygous sort in a much shorter period.

Near homozygous strains are easily recognized. All plants approach uniform habit for morphological characters as well as in size and vigor. Crosses between such self-fertilized strains are uniform and very vigorous as a rule. Remarkable yields have been obtained from such crosses.

It was easily recognized that vigor in corn was closely related to the heterozygous condition. The explanation of the reason for these results was not entirely satisfactory. A recent hypothesis is of much interest (14). Vigor in corn is explained as due to the presence of certain necessary growth factors. Self-fertilization isolates sorts which are homozygous for certain of these factors. The cross which yields the highest is supposed to contain the largest number of factors necessary to most vigorous development. Each growth factor produces nearly as great an effect when heterozygous as when homozygous. Linkage is used to explain why no selfed sort has been obtained with as high yielding ability as that of crosses. Whether this explanation is essentially correct can only be determined from further investigation. It satisfactorily accounts for all the facts involved and helps the breeder to correlate results. An appreciation of these facts has considerable bearing on the technic of breeding.

There are three possible means of utilizing increased vigor from crosses. These will be considered under the headings of (a) first-generation variety crosses; (b) first-generation crosses between self-fertilized strains; and (c) synthetic production of a variety by self-fertilization, crossing, and subsequent selection.

FIRST-GENERATION VARIETY CROSSES.

A suggestion for utilization of first-generation variety crosses was made by Morrow and Gardner (22) in 1893. Many comparisons of such varietal crosses have been made due to a growing appreciation of the results from self-fertilization and crossing. These results have shown that, on the average, first-generation crosses may be ex-

pected to yield more than the average of the parents (3, 8, 12, 17). Some few tests have given negative results. As an example, Kiesselbach (18) found varietal crosses with Hogue Yellow Dent as the male parent were no better than the parental averages. He concludes that there is no value in F_1 crosses between adapted varieties.

During the last four years varietal crosses have been compared with their parents at the Minnesota station. Minnesota No. 13 was used as the male parent in all cases. The adapted dent varieties, Rustler, Silver King, Murdock, and Minnesota No. 23, have been crossed with Minnesota No. 13. Longfellow, Smutnose, Mercer, and King Phillip have been used as flint parents. Crosses of Minnesota No. 13 with Rustler, Minnesota No. 23, and Silver King have been compared with their parents for a 4-year period, while the Murdock × Minnesota No. 13 cross has been tested for three years, Longfellow × Minnesota No. 13 for four years, and King Phillip × Minnesota No. 13 and Smutnose × Minnesota No. 13 for two years. Average results are presented in Table 1.

TABLE 1.—*Yields of first-generation crosses and their parents.*[a]

Variety.	Yield on a percentage basis with Minn. No. 13 as 100.	Variety.	Yield on a percentage basis with Minn. No. 13 as 100.
Minn. No. 13	100.0	Minn. No. 23 × No. 13	110.9
King Phillip	100.0	Rustler	112.1
King Phillip × No. 13	119.9	Rustler × No. 13	112.4
Longfellow	100.5	Silver King	100.9
Longfellow × No. 13	119.6	Silver King × No. 13	106.7
Smutnose	110.8	Murdock	80.3
Smutnose × No. 13	127.6	Murdock × No. 13	101.6
Minn. No. 23	96.7		

[a] See Minn. Agr. Expt. Sta. Bul. 183.

The varieties used were selected because they were adapted for growing in this section of Minnesota. Remarkable increases in yield were obtained from the crosses between 8-rowed flints and Minnesota No. 13. Similar high yields have been obtained from the F_1 of flint-dent crosses grown at the Connecticut station. The high yield of the F_1 of the Minnesota No. 13-flint cross may be partially explained by the fact that the dent has been so closely selected to type. In interspecies crosses it is reasonable to suppose that two groups of growth factors have been brought together which differ more widely than in the case of intraspecies crosses. This may explain why flint-dent crosses are so vigorous.

CROSSES BETWEEN SELF-FERTILIZED STRAINS.

Shull (24, 25) first suggested the utilization of crosses between self-ferilized sorts as a means of increasing yield in corn. Many data have been accumulated which show that such crosses are a means of obtaining high yields. The chief objection to this method is that self-fertilized strains are of low yielding capabilities and that the seeds obtained from selfed lines are generally much smaller than those obtained from normally pollinated corn. Even though crosses between self-fertilized lines yielded very vigorously the method has not seemed commercially desirable. Low yields of seed per acre would increase the cost of seed. Under unfavorable conditions the food supply of the seed might not give the young plant a vigorous start. This objection has been overcome by a recent suggestion of Jones (16). After isolating selfed strains, tests are made to determine which four biotypes are most desirable as parents.

Suppose these biotypes are numbered, 1, 2, 3, and 4, respectively. Now 1 and 2 are crossed, also 3 and 4, by detasseling all of one biotype in each group. Seed from the plants of each detasseled biotype is then planted in alternate rows in an isolated plot and all of one combination detasseled. Seed from these detasseled rows are used for commercial planting.

By this method good yields of seed can be obtained. If sufficient increases in yield are secured the cost of the initial work would not be prohibitive.

At the Connecticut station such a cross was compared with the best dent variety obtained after making a careful varietal survey. The cross yielded 112 bushels per acre, the best dent variety only 92 bushels. This remarkable difference shows the method deserves further trial.

SYNTHETIC PRODUCTION OF A NEW VARIETY.

The synthetic production of an improved variety by inbreeding and crossbreeding seems a reasonable plan. A normal variety is a mixture of many types. Undesirable characters are sometimes apparent altho due to heterozygosis they are frequently covered. Extreme instances of these are plants which lack the ability to produce chlorophyll and dwarf plants.

Emerson and East (7) have outlined a method for the production of high oil corn as an example of inbreeding and crossbreeding in variety improvement. This suggestion is based upon the fact that selection produces nothing new but isolates races which are pure for certain characters.

The remarkable selection experiments which have been carried on with corn at the Illinois station are well known. By continuous selection strains were produced which differed widely in oil and protein content.

In 1896 normal corn of the variety Burr White had a composition of 4.70 percent oil and 10.92 percent protein. At the end of ten years' selection for high and low protein and high and low oil content, four strains were obtained (26). In 1915 the percentage composition of these strains for the character for which they have been selected was 14.53 and 7.26 protein and 8.46 and 2.07 for oil. Castle[3] (2) has cited these results as in opposition to the pure-line theory. He says, "They show that valuable new varieties are not discovered as the mutation theory holds, but may be created by a process of selection." Surface (27), however, in analyzing the Illinois results has maintained that they indicate that selection has isolated strains which were originally present in the varieties.

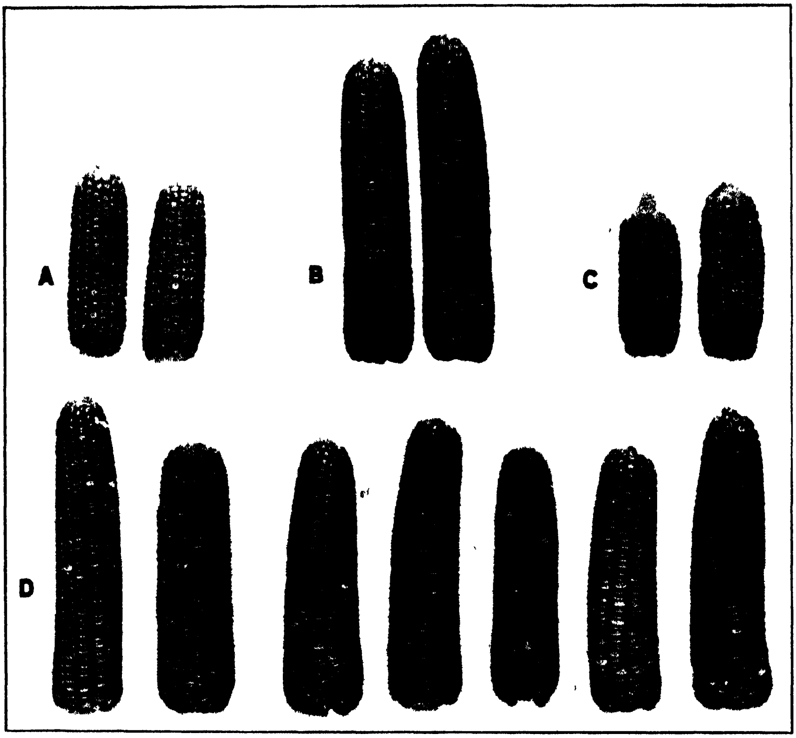
One of the writers started an experiment at the Connecticut station in 1911 with the purpose of learning the mode of inheritance of protein and to determine the possibility of producing high and low protein varieties by selfing and crossing. The method outlined seemed especially adapted to the production of high-protein races, since data indicated that low protein was a dominant character (9). This evidence came from the analysis of ears produced by F_1 plants of crosses between Illinois high and low protein strains and a Connecticut dent variety.

In 1915 an experiment was started at the Minnesota station for the purpose of trying to produce a high-protein strain of Minnesota No. 13[4]. The method was to self-fertilize a number of ears and analyze each ear for protein. High-protein self-fertilized ears were then used as parents. The plan was to isolate a number of high-protein strains and then determine which produced the highest yields when crossed. The better yielding cross was then to be planted in an isolated plot and selected for vigor. No new variety is yet ready for distribution, but the results show that the method is reliable.

Certain facts have been discovered in this work which, if appreciated earlier, would have been of material value, since only single pollinations were made for each selfed ear and as conditions were variable, some ears contained many more seeds than others.

[3] For Castle's recent viewpoint on the effect of selection, see Amer. Nat., 53: 370–375. 1919.

[4] The analyses of protein presented in this paper were made by the Division of Agricultural Biochemistry. The protein percentages are on a dry basis.



Average ears of strain No. 2, Minnesota No. 13 corn, selfed four years (*A*); F_1 ears of the cross between strain 2 and strain 4 (*B*); average ears of strain 4, Minnesota No. 13, selfed four years (*C*); and ears of Minnesota No. 13 showing various types of ears produced (*D*).

Self-fertilized ears were obtained in 1918 from first-generation crosses between high-protein strains. A direct negative correlation was observed between the number of seeds per ear and protein content.

Table 2 shows this correlation. *A, B,* and *K* are crosses between different ears of the same high-protein strains. They gave very similar results for average protein content.

TABLE 2.—*Correlation between number of kernels of self-fertilized ears and their respective percentages of protein on a dry basis.*

Number of kernels per ear	Protein percentages. 12.75	13.25	13.75	14.25	14.75	15.25	15.75	16.25	16.75	17.25	17.75	
25									2			2
75										1		1
125							1	3	2	1	2	9
175							3	3	4	2		12
225							2	3	2		1	8
275		2		1	1	4	3	3	1			15
325	2		1		3	2	4	3	1			16
375			1	1	1			1				4
	2	2	2	2	5	6	13	16	12	4	3	67

Correlation coefficient $= -.601 \pm .053$.

The correlation table and calculated coefficient show a high negative relation between number of seeds produced per ear and protein content.

There is little, if any, immediate effect of foreign pollen on the protein percentage the year that a cross is made. Table 3 shows the average percentage of protein in selfed ears of high and intermediate strains and from F_1 crosses between them.

TABLE 3.—*Immediate effect of crossing on protein content.*

Strain No.	Years selfed.	Average protein content of ears (1918). Percent.
1	4	14.92
2	4	15.46
3	4	16.76
4	4	15.09
8	4	12.97
9	4	12.53
Average of 1 or 2 × 3 or 4		17.14
Average of 1 or 2 × 8 or 9		16.89

These results seem sufficient to indicate that there is little, if any, effect on protein content due to the immediate effect of pollination.

Since the ears produced by crossing selfed sorts contained, as a rule, fewer seeds than selfed parental ears, the protein content of the crossed ears average somewhat higher.

An analysis was made of a composite sample of open field pollinated progeny of each selfed ear. Each strain was then further propagated by using as a parent the selfed ear which produced a high average protein content. Results for the average protein content of the composite samples are given in Table 4.

TABLE 4.—*Protein content of selfed strains of Minnesota No. 13 and crosses between them.*

Strain No.	Average protein content.		
	1916.	1917.	1918.
	Percent.	*Percent.*	*Percent.*
1	15.82	14.03	15.10
4	14.47	13.06	14.93
Normal No. 13		10.17	10.25
1 x 4, F_1 Ear A			12.25
1 x 4, F_1 Ear B			12.44
1 x 4, F_1 Ear K			12.81

The season of 1915 when the initial self-fertilizations were made was very unfavorable for corn and consequently only 127 selfed ears were obtained. Two strains were isolated which gave much higher percentages of protein than normal pollinated corn. These strains have not varied very widely during the three years that they have been grown. Crosses between these two strains were made in 1917 and individual rows were grown during the season of 1918. Even though the parental strains had been selfed for only two years the F_1 crosses were very uniform. The bulk analysis showed that the crosses yielded on the average a little over 2 percent more protein than normal pollinated Minnesota No. 13. Ears of parental strains 2 and 4, F_1 ears of the cross between these strains, and normal ears of Minnesota No. 13 corn are shown in Plate 10. Whether strains with higher protein content than the ones here presented can be isolated from Minnesota No. 13 is not yet known.

Comparative yields from these crossed strains and Minnesota No. 13 were obtained. The yields are based on the weight of corn obtained after storing in a heated room until January 1, 1919. Normal pollinated Minnesota No. 13 gave a yield of 48.9 bushels per acre while the yields of the three F_1 crosses, *A*, *B*, and *K*, were respectively 51.4, 51.3, and 54.2 bushels per acre.

These F_1 crosses were planted in an isolated plot in 1919. Selection on the basis of vigor will be made in the field.

SUMMARY.

A discussion of the effect of inbreeding and crossbreeding in relation to corn improvement is made. The writers believe that there are almost unlimited opportunities of improving corn by an application of these principles.

An experiment is outlined for the synthetic production of high-protein corn by self-fertilization, crossing, and subsequent selection. Three F_1 crosses between high-protein strains were studied in 1918. They were compared with Minnesota No. 13 which was the original source of the selfed strains. They gave an increase in average protein content of a little over 2 percent as compared with Minnesota No. 13 and also yielded somewhat better.

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NITROGEN LOSSES IN URINE.[1]

FIRMAN E. BEAR AND J. R. ROYSTON.

INTRODUCTION.

Considerably more than half of the nitrogen of manure is contained in the urine. Thorne (6)[2] gives the relative percentages of nitrogen in the dung and urine of dairy cows collected over a period of 24 hours as 0.26 percent for the dung and 1.32 percent for the urine. Investigation has shown that where the urine is properly absorbed by litter and kept well packed under cover only slight nitrogen losses occur. On the modern dairy farm, however, the urine is collected in tanks without any absorbing material. As the urine usually stands in these tanks over a period of several months before being sprinkled upon the fields, the question naturally arises as to the loss of nitrogen in this method of preserving the urine.

Nitrogen losses in urine by fermentation are due to the change of the urea and other nitrogen compounds to gaseous forms. The principal compound formed is ammonium carbonate, which easily breaks down to form ammonia, carbon dioxide, and water. When fresh urine comes in contact with putrid urine, as in the case of storage tanks, fermentation takes place rapidly, due to the organisms with which the putrid urine is charged.

Storer (5) states that, with cow urine kept in tightly covered tanks, a loss in nitrogen of about 2 percent per month was observed. Vogel (7) observed that urine protected by an oil covering showed no appreciable loss of nitrogen. Without the oil covering and with long exposure the nitrogen losses were very marked.

In the investigations of Kristensen and Hansen (3) the manner of covering liquid manure tanks was found to be of great importance. Cow urine, kept in carefully covered tanks, contained on the average 0.615 percent of nitrogen, while that from poorly covered tanks contained only 0.285 percent. The maximum amount of nitrogen in samples from carefully covered tanks was 0.836 percent and the minimum from poorly covered tanks was 0.169 percent. These results

[1] Contribution from the Department of Agricultural Chemistry and Soils, Ohio State University, Columbus, Ohio. Received for publication June 30, 1919.

[2] Reference is to "Literature cited," p. 326.

were obtained from examination of the liquid manure on a number of Danish farms. Further experiments were conducted by Kristensen (4) on the storage of liquid manure in a cistern 9.5 feet deep and 17 feet wide for a period of 8 months. It was found that the nitrogen content of the liquid during this period decreased from 0.447 percent to 0.350 percent, a loss of 21.7 percent. This loss is explained by the fact that there was an opening 3 inches wide and 6 inches long in the cover of the cistern thru which the pump projected.

Laboratory experiments conducted by Deherain (1) for the purpose of explaining the losses of nitrogen from manure resulted briefly as follows: A solution of ammonium carbonate lost 73 percent of its nitrogen when exposed to the air for 30 days. In a closed flask, in which was suspended a dilute solution of sulfuric acid to absorb the ammonia, the ammonium carbonate lost 12.1 percent of its nitrogen in 3 days and 24.2 percent in 8 days. In closed flasks, provided with sulfuric acid to absorb the ammonia and sodium hydroxide to absorb the carbon dioxide, 39.3 percent of the nitrogen escaped in 3 days and 83 percent in 8 days.

Urine was then substituted for the ammonium carbonate solution and similar experiments conducted with it. When exposed to the air for a period of one month the urine lost 45 percent of its nitrogen. In a closed flask the loss in the same time was only from 5.6 to 6.6 percent. In flasks provided with sulfuric acid to absorb the ammonia, 21 percent of the nitrogen escaped in 5 days, but at the end of that time none of the ammonia formed had been absorbed by the sulfuric acid. At the end of 11 days, however, 19 percent of the nitrogen of the urine was found in the sulfuric acid. When provision was made for the absorption of both the ammonia and carbon dioxide in a closed flask there was a loss of only 2.9 percent of the nitrogen in 5 days, but of 52 percent in 11 days.

In experiments in which litter was used to absorb the urine (1 part litter to 2 parts urine) the loss of nitrogen in the open air during the summer was 7.2 percent in 8 days. In closed flasks in which arrangements were made for the absorption of the ammonia and carbon dioxide, 7.9 percent of the nitrogen escaped in 3 days, 31.5 percent in 6 days, 52.6 percent in 8 days and 59.7 percent in 12 days. In an atmosphere of carbon dioxide no nitrogen escaped from the mixture, altho the larger part of the nitrogen was converted into ammonia. The author concludes that this is the condition in a well-constructed and well-compacted manure heap.

OBJECT OF THESE INVESTIGATIONS.

It would appear from the above that a considerable amount of work has been done to determine the losses of nitrogen from urine. However, it seemed desirable to repeat and supplement some of the above work under controlled conditions in order that we might have a somewhat more definite conception of what this loss is under storage conditions such as obtain in America.

PLAN OF THE EXPERIMENT.

About 5 gallons of fresh urine were collected from the University herd of dairy cows early one morning when the cows first arose on being fed. Particles of dung were placed on muslin and the urine poured over them, thus inoculating the liquid with the intestinal flora. The urine was immediately removed to the laboratory.

The method of procedure was planned with two general objects in view, viz: (1) to determine the losses of nitrogen from samples of urine exposed to the air in open beakers for varying periods of time at temperatures approximating winter and summer; and (2) to determine the losses of nitrogen in samples of urine confined in flasks under the same temperatures with no evaporation permitted to take place. Accordingly, two series of trials were conducted.

In Series I, duplicate 400-c.c. portions of urine were placed in 600-c.c. beakers and exposed to the air for periods of 1, 2, 4, 8, and 12 weeks, respectively. Duplicate samples representing each period of time were exposed in both the basement and attic of the building. The average temperature over the 12-week period from January 18 to April 12 was 32.5° C. for the basement and 38° C. for the attic. These temperatures were taken daily at noon and variations were recorded by means of the thermograph.

Included in Series I were three duplicate samples of 400 c.c. of urine covered with half-inch layers of kerosene. These were exposed at 32.5° C. for periods of 1, 4, and 8 weeks. Also, two portions in duplicate of 20 c.c. of urine were placed in 600-c.c. beakers, absorbed with filter paper, and exposed to the air for a period of 8 weeks. One sample in duplicate was allowed to evaporate to dryness while the other was kept constant in weight by the addition of water from day to day. Blank beakers containing 400-c.c. portions of water were used to absorb any free ammonia in the air.

In Series II, duplicate 200-c.c. portions of urine were placed in 500-c.c. graduated flasks equipped with Bunsen valves. These flasks were subjected to the same temperatures for the same periods of time as Series I.

In addition to the flasks equipped with Bunsen valves three sets of duplicate samples were placed in tightly stoppered flasks and allowed to stand for periods of 1, 4, and 8 weeks, respectively. Likewise, three sets of duplicate samples were placed in tightly stoppered flasks in which the air had been replaced by an atmosphere of carbon dioxide. These also were allowed to stand for periods of 1, 4, and 8 weeks, respectively.

As the different periods of time expired in each series, the nitrogen in the samples was fixed by the addition of sulfuric acid and the volume was made to 500 c.c. with water. At the end of the 12-week period aliquots containing 1 c.c. of urine were analyzed for total nitrogen by the Kjeldahl-Gunning method.

LOSSES OF NITROGEN FROM URINE IN OPEN FLASKS.

It will be observed in Table 1 that there was a continual loss of nitrogen from the urine exposed to the air at 38° C. all thru a period of 8 weeks. The most rapid loss took place during the third and fourth weeks. At the end of 8 weeks the maximum losses under the conditions which obtained had evidently occurred. Those samples allowed to stand for a period of 8 weeks evaporated to about half their original volume of 400 c.c., while those which stood for the 12-week period were reduced to about 80 c.c.

TABLE 1.—*Nitrogen losses from urine exposed to the air at average temperatures of 38° and 32.5° C.*

Average temperature of 38° C.				Average temperature of 32.5° C.			
Sample No.	Time exposed.	Nitrogen.	Loss.	Sample No.	Time exposed.	Nitrogen.	Loss.
	Weeks.	*Percent.*	*Percent.*		*Weeks.*	*Percent.*	*Percent.*
0	Fresh	1.63	....	....	....	....	....
1	1	1.46	10.42	13	1	Lost	....
2	1	1.46	10.42	14	1	1.60	1.84
3	2	1.07	34.35	15	2	1.51	7.36
4	2	1.09	33.12	16	2	1.48	9.20
5	4	.58	64.41	17	4	1.29	20.85
6	4	.57	65.03	18	4	1.29	20.85
7	8	.13	92.03	19	8	.50	69.32
8	8	.13	91.71	20	8	.50	69.32
9	12	.12	92.63	21	12	.14	91.41
10	12	.13	92.03	22	12	.13	92.02
11[a]	12	0.	....	23[a]	12	0.	....
12[a]	12	0.	....	24[a]	12	0.	....

[a] Samples 11, 12, 23, and 24 were water blanks to determine the amount of ammonia absorbed from the air.

With a temperature of 32.5° C. the most rapid loss took place between the fourth and eighth weeks. For the entire 12-week period, however, the nitrogen losses approached the apparent maximum limit of about 92 percent. The loss in volume by evaporation at the lower temperatures was somewhat less than that of samples subjected to 38° C. Samples exposed for 8 weeks evaporated to about two-thirds their original volume of 400 c.c., while those which remained for 12 weeks were reduced to about 170 c.c. each.

The oil-covered samples (Table 2) retained their original volumes thruout the period of the experiment with no appreciable evaporation of the kerosene. The loss of only 6.13 percent of total nitrogen for a period of 8 weeks as shown in Table 3 demonstrates the effectiveness of this simple method in conserving the nitrogen of the urine. It is probable that some of this loss occurred during the process of separating the oil from the urine, this being necessary before the sulfuric acid could be added to fix the nitrogen.

TABLE 2.—*Nitrogen losses from urine protected by oil or absorbed in paper when kept at an average temperature of 32.5° C.*

Protected by oil.				Absorbed in paper.			
Sample No	Time exposed.	Nitrogen.	Loss.	Sample No.	Time exposed.	Nitrogen.	Loss.
	Weeks.	*Percent.*	*Percent.*		*Weeks.*	*Percent.*	*Percent.*
25	1	1.59	2.45	31[a]	8	1.38	15.33
26	1	1.59	2.45	32[a]	8	1.22	25.15
27	4	1.57	3.68	33[b]	8	.05	96.93
28	4	lost	——	34[b]	8	.04	97.54
29	8	1.53	6.13				
30	8	1.53	6.13				

[a] Samples allowed to evaporate to dryness.
[b] Samples kept constant in weight by the addition of water daily.

That phase of the experiment wherein urine was absorbed in filter paper was designed with the idea of obtaining data concerning the losses of nitrogen when the urine is absorbed by litter and exposed to the air. Pieces of filter paper were spread upon the bottom of the beaker in a flat, compact fashion until all the urine was absorbed. Samples 31 and 32 lost their moisture by evaporation within the first week, at the rate of approximately 3.5 grams daily. At the end of the 8-week period they were air dry and had lost 18.0 and 18.1 grams in weight, respectively. Samples 33 and 34, kept constant in weight by the addition of water daily, soon lost the characteristic odor of urine. The dry samples, on the other hand, retained this odor thruout the period.

It will be seen that the samples kept in a moist condition by the addition of water lost practically all of their nitrogen, 97.23 percent. From this it would seem that manure lying exposed to rain and sunshine would be subject to great losses of nitrogen from fermentation and evaporation. In the dry samples, fermentation was probably checked by the lack of moisture, unfavorable conditions for bacterial action resulting. The loss in this case amounted to only 20.34 percent.

LOSSES OF NITROGEN FROM URINE CONFINED IN FLASKS.

The object of this part of the experiment was to control the factor of evaporation without interfering with the normal bacterial activities taking place in the urine. Accordingly, flasks were fitted with Bunsen valves to allow the escape of gases from within without permitting the access of air. Table 3 shows the results obtained.

TABLE 3.—*Nitrogen losses in urine in Bunsen valve flasks at temperatures of 38° and 32.5° C.*

Average temperature of 38° C.				Average temperature of 32.5° C.			
Sample No.	Time exposed.	Nitrogen.	Loss.	Sample No.	Time exposed.	Nitrogen	Loss.
	Weeks.	*Percent.*	*Percent.*		*Weeks.*	*Percent.*	*Percent.*
1[a]	1	1.56	3.98	11	1	1.62	0.61
2	1	1.62	.61	12	1	1.63	none
3	2	1.62	.61	13	2	1.63	do.
4	2	1.62	.61	14	2	1.61	1.22
5	4	1.65	1.22[b]	15	4	1.63	none
6	4	1.59	2.45	16	4	1.62	.61
7	8	1.64	.61[b]	17	8	1.62	.61
8	8	1.63	none	18	8	1.62	.61
9	12	1.63	do.	19	12	1.63	none
10	12	1.62	.61	20	12	1.61	1.22

[a] Loss by foaming on addition of H_2SO_4.
[b] Gain.

A consideration of the analyses in Table 3 will show that the losses of nitrogen from the urine confined in the Bunsen valve flasks are so small as to be easily within the limits of experimental error. In several samples large white crystals were observed. When treated with concentrated sulfuric acid they readily dissolved with effervescence. This would indicate a carbonate, probably $(NH_4)CO_3$.

Table 4 further substantiates the conclusion drawn from Table 3 that nitrogen losses occur only under aerobic conditions. A part of the samples were kept in tightly stoppered flasks thruout the various

periods of time, while in others the air was displaced by an atmosphere of carbon dioxide. When the stoppers were withdrawn from the latter flasks a partial vacuum was observed in each flask. These samples also showed quite noticeable odor in contrast with the other samples. The color of the urine in these flasks was similar to that of the original.

TABLE 4.—*Nitrogen losses in urine in closed untreated flasks and in closed flasks in which the air was displaced by carbon dioxide, the average temperature in each case being 32.5° C.*

Closed flasks with air.				Closed flasks with carbon dioxide.			
Sample No.	Time exposed.	Nitrogen.	Loss	Sample No.	Time exposed	Nitrogen.	Loss.
	Weeks.	*Percent.*	*Percent.*		*Weeks.*	*Percent.*	*Percent.*
21	1	1.61	1.22	27	1	1.63	none
22	1	1.62	.61	28	1	1.63	do.
23	4	1.63	none	29	4	1.63	do.
24	4	1.63	do.	30	4	1.63	do.
25	8	1.63	do.	31	8	1.61	1.22
26	8	1.63	do.	32	8	1.63	none

SUMMARY.

An inquiry into the losses of nitrogen from the urine of farm animals was thought desirable because many farmers practice storing the liquid manure in tanks until convenient to apply it to the land. The question of the efficiency of these tanks in preserving the urine has often arisen. In these investigations a study was made as to nitrogen losses from urine (*a*) exposed to the open air, (*b*) in Bunsen valve flasks, (*c*) in closed flasks, (*d*) in closed flasks with the air displaced with carbon dioxide, (*e*) absorbed in litter, and (*f*) protected by layers of kerosene.

It was observed that urine exposed to the air lost over 92 percent of its nitrogen over a period of 8 weeks under temperatures averaging 38° C. Under temperatures averaging 5° less, approximately the same losses occurred over a period of 12 weeks. For shorter periods of time the losses were somewhat smaller at the lower temperatures.

With urine not exposed to the air practically no losses took place under the various conditions of temperature, time, and methods of control.

The effectiveness in preventing nitrogen losses by absorption of the urine in litter (filter paper) depended upon the method of handling the litter. Litter which was allowed to dry out and remain dry lost approximately 20 percent of its nitrogen content. On the other hand,

litter kept in a moist condition by the daily addition of water lost over 97 percent of its nitrogen, the greatest loss which occurred in any of the samples.

Kerosene proved a fairly satisfactory means of preventing nitrogen losses. The samples of urine so protected lost approximately 6 percent of their nitrogen content over a period of 8 weeks.

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THE MANURIAL VALUE OF A MODIFICATION OF ORTHO-CLASE-BEARING ROCK WHERE ONLY POTASSIUM WAS DEFICIENT.[1]

BURT L. HARTWELL.

In July, 1912, the Institute of Industrial Research, Washington, D. C., after being in touch for a number of months with operations conducted on a mill scale by the Cushman-Coggeshall process, which had involved nearly 400 tons of raw material, stated that the treatment of feldspathic rock had been made economically and commercially possible; but that it was desired to have agricultural tests conducted before proceeding much further with the development of the technical and commercial possibilities involved in the production of the form of "rock potash fertilizer" under consideration. The purpose of this paper is to report the results of an inextensive field trial conducted with this material at the Rhode Island station during six years, now that this test has been terminated.

The following information concerning the manufacture of the material has been furnished by the Institute of Industrial Research. The proper proportion of lime and feldspathic rock was ground together, and as the mixture was conveyed over a moving drum, a strong solution of calcium chlorid was sprinkled over it. This enabled the formation of the material into clumps, from which the fine particles were sifted for subsequent treatment. The clumped material, about the size of peas, travelled continuously thru the rotary kiln where it was subjected to special heat treatment, after which it was rough ground in preparation for use. The finished product was said to consist mainly of silicates of aluminum, free lime, and potassium chlorid, a typical analysis being given as follows: Water-soluble potassium oxid, 4.3 percent; total potassium oxid, 5.7 percent; total calcium oxid, 16.0 percent.

The orthoclase feldspar which was used was quarried principally in Maryland and contained about 10 percent of potassium oxid. Arguments which have been advanced against the commercial adoption of the method were that it would be impossible to get feldspar

[1] Contribution 261 from the Agricultural Experiment Station of the Rhode Island State College, Kingston, R. I. Received for publication August 12, 1919.

that could be depended upon to run more than 8 percent potassium oxid and that the percentage in the mixture including the lime and calcium chlorid was so low that very little opportunity was left for incorporating sources of nitrogen and phosphorus so that a complete fertilizer might be produced.

Six twelfth-acre plats of Warwick sandy loam soil were used for the experiment. All were kept supplied with equal optimum amounts of nitrogen, phosphorus, and lime. One of the plats did not receive any of the potassium, and one received a liberal amount, probably beyond the needs of the crops. The other four plats were given only a small amount of potassium, which was expected to be less eventually than the optimum requirements. These enabled a duplicated comparison to be made between the effect of a high-grade commercial potash salt, sulfate or muriate, and of the rock potash fertilizer when furnishing the same amount of water-soluble potassium.

In the spring of 1913, several months after the rock potash fertilizer was received, it was found to contain 3.87 percent of potassium oxid soluble in water by the method of the Association of Official Agricultural Chemists. This determination was used as the basis of comparison thruout the experiment.

To prevent the lime in the rock potash fertilizer from exerting any effect, in order that the value of the latter as a source of potassium only might be determined, 1 ton of ground limestone was applied per acre in 1913, and 1 ton of slaked lime together with 1,700 pounds of ground limestone in 1915.

In 1913, the maximum application of potassium oxid was 60 pounds per acre, and the smaller amount was 20 pounds; but the check plat without any potassium yielded fully as much corn, about 35 bushels, as where it was applied.

In 1914, the potassium applications of the previous year were repeated and a crop of soybeans was grown for green manure, as the gravelly soil was quite poor in organic matter; this crop was followed by rye as a cover crop.

In 1915, the suboptimum application of potassium oxid was increased to 30 pounds per acre, and the maximum to 90 pounds. Early potatoes were grown and it became evident during their development that there was finally a deficiency of potassium except where the maximum amount was applied. The bushels of potatoes produced per acre were 86 on the check plat, an average of 122 on the plats receiving muriate of potash, an average of 130 on the plats receiving, in the rock potash fertilizer, the same amount of soluble

potassium, and 206 on the plat receiving three times that amount or about 2,300 pounds per acre. Rape, soybeans, millet, and barley were grown after the early potatoes for turning in as green manure, and rye planted as a cover crop.

In 1916, the suboptimum and maximum applications of potassium oxid were increased to 50 and 100 pounds per acre respectively. White beans were grown but the yields were so inferior that they had no significance from the standpoint of the experiment. Rye was again sown as a winter cover crop.

In 1917, the potassium applications of the previous year were repeated and early potatoes planted. The yields per acre were 233 bushels on the check plat, 261 with sulfate of potash, 285 with the rock potash fertilizer supplying the same amount of soluble potassium, and 302 when twice the amount was added.

After the removal of the potatoes, alfalfa was sown broadcast. In the spring of 1918, the same amounts of potassium oxid, 50 and 100 pounds, were applied. Two crops of alfalfa hay amounted, in tons per acre, to 2.40 where there was no application of potassium, 2.57 where sulfate of potash was added, 2.76 with the same amount of soluble potassium added in rock fertilizer, and 3.15 where twice as much was added.

The efficiency of the two sources of potassium may be seen plainly by assembling the acre yields as shown in Table 1.

TABLE 1.—*Yields of potatoes and alfalfa obtained from the use of various potash fertilizers.*

Fertilizer applied	1915, potatoes.	1917, potatoes.	1918, alfalfa.
	Bushels	*Bushels*	*Tons*
Check	86	233	2.40
Suboptimum potassium:			
in muriate or sulfate of potash	122	262	2.57
in rock potash fertilizer	130	285	2.76
Optimum potassium	206	302	3.15

The foregoing shows that under nutrient conditions which were believed to be suboptimum for only potassium, the rock potash fertilizer was slightly more efficient than high-grade muriate or sulfate of potash when supplying the same amount of water-soluble potassium.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership of the Society reported in the October number was 541. Since that time 8 new members have been added and 1 who was listed as resigned in a previous issue has rejoined the Society, so that the present membership is 550. The names and addresses of the new members and of the member who has rejoined, together with such changes of address as have been reported, follow.

New Members.

Ayers, W. E., 531 E. Jones St., Sherman, Texas.
Cobb, J. Stanley, Agronomy Dept., State College, Pa.
Donald, Lewis R., Agronomy Dept., State College, Pa.
Feilitzen, Phil Hjvon, Moor Experiment Station, Jonkoping, Sweden.
Hinde, R. R., 211 N. Juliet Ave., Manhattan, Kans.
Lewis, R. D., Agronomy Dept., State College, Pa.
Potts, H. W., Agricultural College, Richmond, New South Wales.
Wilkinson, Walter, University Farm, Davis, Cal.

Member Reinstated.

Call, L. E., Dept. of Agronomy, Kansas State Agr. College, Manhattan, Kans.

Changes of Address.

Bull, C. P., Worthington, Minn.
Chapman, James E., 2316 Pierce Ave., St. Paul, Minn.
Clark, Chas. F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Cormany, Chas. E., 109 Catherine St., Ithaca, N. Y.
Gillis, M. C., 208 Delaware Ave., Ithaca, N. Y.
Hagy, F. S., Kenton, Ohio.
Haseltine, L. E., Hotel Shattuck, Berkeley, Cal.
Runk, C. R , Tippecanoe City, Ohio.
Tinsley, J. D., 606 Union Station Bldg., Galveston, Texas.
Viola, N. E., Hohentwil, Hombrechtikon, Switzerland.
Wheeler, Clark S., 103 W. Miami Blvd., Dayton, Ohio.
Wilkins, F. S., Dept. of Agronomy, College of Agriculture, Corvallis, Ore.
Winters, N. E., 1414 E. Fourth St., Charlotte, N. C.

NOTES AND NEWS.

C. P. Bull, formerly agronomist in charge of cooperative experiments at the Minnesota station, is now with the Humiston-St. John Seed Co. at Worthington, Minn.

G. I. Christie, director of agricultural extension in Indiana, is superintendent of the International Grain and Hay Show which will be held in Chicago in connection with the International Livestock Exposition, November 29 to December 8.

A. H. Cockayne, biologist of the New Zealand Department of Agriculture, is spending several months in the United States, where he is studying agricultural methods and organization.

J. A. Drake, who has been connected with the Federal Office of Farm Management since 1906, is now agricultural editor of *Farm, Stock and Home*.

H. B. Fuller, of the Office of Extension Work in the North and West, States Relations Service, is now county agent leader in North Dakota, succeeding R. C. Pollock, who will do extension work for the Holstein-Friesian Association.

Paul Emerson, formerly associate bacteriologist of the Idaho station, is now assistant professor of soils and assistant chief in soil bacteriology at the Iowa State College. At the same institution, H. W. Johnson has been promoted from assistant in soil bacteriology to associate professor of soils and assistant chief in soil chemistry in humus investigations.

J. C. Hackleman, formerly extension agronomist in Missouri, is now extension agronomist in Illinois.

Cyril G. Hopkins, chief of agronomy and agricultural chemistry in the University of Illinois since 1900, died at Gibraltar, October 6, while on his return journey from Greece, where he has been engaged for the past year in a study of the worn soils of that country for the American Red Cross. Doctor Hopkins was born in Minnesota in 1866, graduated from the South Dakota Agricultural College in 1890, received his master's and doctor's degrees from Cornell University, and pursued advanced studies in agricultural chemistry at Gottingen in 1899 and 1900. He was a prolific writer on soil-fertility subjects, being the author of several books as well as numerous bulletins and articles in the farm press. Shortly before leaving Greece, he was decorated by the king for distinguished service. His death was due to congestion of the brain, with malarial complications.

DeForest Hungerford, formerly assistant agronomist of the Arkansas station, is now farm management specialist with the extension department in Georgia.

L. S. Klinck, for the past several years dean of the college of agriculture of the University of British Columbia, is now president of that institution.

C. W. Mullen, assistant professor of farm crops at the Kansas college, resigned November 1 to become associate editor of the *Oklahoma Stockman and Farmer,* and has been succeeded by J. W. Zahnley, formerly of the department of education in the same institution.

J. C. Russell, formerly assistant in chemistry at Nebraska Wesleyan University, is now assistant professor of soils at the University of Nebraska.

B. F. Sheehan, formerly assistant professor of farm crops in the Oregon college, is now extension agronomist and state seed commissioner in Idaho, with headquarters in Boise. He has been succeeded in Oregon by F. S. Wilkins, formerly of the Iowa college.

R. S. Snyder, formerly assistant in soil chemistry at the Iowa college and station, is now assistant chemist of the Idaho station.

Geo. F. Stuntz is now assistant agronomist of the Maryland station, succeeding W. J. Aitcheson.

R. O. Westley, formerly assistant professor of agronomy in the Northwest School of Agriculture at Crookston, Minn., is now instructor in farm crops in the Washington college.

Clark S. Wheeler, director of the agricultural college extension service of Ohio State University, resigned November 1 to become assistant to the sales manager of the Domestic Manufacturing Company of Dayton, Ohio.

Under the new plan inaugurated July 1 in the college of agriculture of the University of California, by which the dean of the college is to nominate annually a director of resident instruction, a director of the experiment station, and a director of extension, Walter Mulford has been named as director of resident instruction for the current year, H. J. Webber director of the experiment station, and B. H. Crocheron director of agricultural extension. J. T. Barrett, professor of plant pathology, is acting director of the Citrus substation and acting dean of the Graduate School of Tropical Agriculture at Riverside in the absence of Doctor Webber.

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TAXING THE AIR FOR INCREASED FOOD PRODUCTION.[1]

J. G. LIPMAN.

Wherever plant food is a limiting factor in crop production, acre yields are affected by the cost of commercial fertilizer as well as by the cost of land and labor and the market value of the crop. Cheap land and a limited supply of labor have, in the past, served to increase the size of the farm rather than the acre yield. In recent years, however, certain changes have come into our economic life, and these changes will compel, if they are not already compelling, a substantial readjustment in our methods of soil treatment.

As measured by European standards our land values may not be inflated, but they fluctuate now at levels much higher than those which prevailed in the memorable year of 1914. An acre of land that costs $300 cannot be neglected without financial discomfort to the owner or tenant. It must yield a return of $20 to meet fixed charges, and it must yield other returns to provide a living for the farmer. High-priced labor tends to become unprofitable under extensive and slovenly methods of production. On the other hand, the higher cost of plant food is more than offset by the increased value of farm products. The diversification in cropping now gaining momentum in certain of our agricultural districts, the increased acreage under crops of high commercial value, the manufacture of secondary agricultural products, and the elimination of the middleman must all tend towards more intensive methods of tillage and cropping.

The readjustments just noted are forcing us to make a careful scrutiny of our plant food resources, to acquaint ourselves with the

[1] Presidential address before the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 10, 1919.

supply and distribution of nitrogenous, phosphatic and potassic fertilizers. We are impelled particularly to take under observation the methods and practices of the Old World farmers who have been driven by the stress of our competition to constantly higher levels of production and who have survived in spite of our cheap and virgin fertility. We are impressed, as we study these Old World practices, by the skill with which nitrogenous manures are employed to supplement the nitrogen resources of the soil itself; how in the use of these the farmers of Belgium, Germany and Great Britain have learned to attain the 30, 40, or even 50 bushel levels in the production of wheat, rye, and barley, to say nothing of the almost extraordinary yields of potatoes and beets.

Without going too far afield, I shall try, with your permission, to discuss only a single phase of our fertilizer and fertility problem, namely, the more systematic and more intensive use of nitrogen compounds that are the resultants of electrochemical and microbiological processes. But before I attempt a discussion of the use of these compounds, I must establish certain premises which relate directly to the gains and losses of nitrogen from the arable land in the United States. Some of the data which I shall now place before you were gathered for another purpose, but will serve very well the purpose which I now have in mind.

LOSSES OF SOIL NITROGEN.

In his report for 1918, Secretary of Agriculture Houston estimates the area devoted to the more important staple crops at 289,073,300 acres. This acreage does not include the cultivated forage crops like alfalfa, timothy, and clover. With these included, the area of arable land in the United States is well above 300,000,000 acres. Taking 300,000,000 acres as a very conservative basis for estimating the gains and losses of nitrogen from arable land in the United States, we find the following:

1. The loss of nitrogen from the average acre of arable land may be taken at 60 pounds per annum. This estimate is based on a careful study of available data in European and American literature. Hence, at 60 pounds per acre, the annual loss from 300,000,000 acres of arable land would correspond to 9,000,000 tons of nitrogen.

2. The losses of soil nitrogen are, in part, offset by applications of animal manures, by the growing of leguminous crops, by atmospheric precipitation, by non-symbiotic nitrogen fixation in soils, and by the use of commercial fertilizers.

It is estimated by Secretary Houston that, in 1918, there were on the farms in the United States approximately 26,000,000 horses and mules, 66,800,000 beef and dairy cattle, 48,900,000 sheep, and 71,400,000 swine. The manure produced by these animals contains an equivalent of 5,250,000 tons of nitrogen. Had all of this nitrogen been available for restoring the loss of this constituent from our arable land, the balance sheet would be a more favorable one than it actually is. It has been clearly demonstrated by numerous studies in this country and abroad that, aside from the nitrogen retained in the bodies of domestic animals, extensive losses of this constituent are caused by leaching and by fermentations in manure. Account should also be taken of the nitrogen left on the ranges and pastures in the droppings of domestic animals. All told, not more than one tnird of the nitrogen calculated as present in the manure of domestic animals is actually made available for crop uses. Hence, it may be assumed that the manure of the domestic animals in the United States annually restores to the arable land of this country an equivalent of 1,750,000,000 tons of nitrogen.

It may be assumed further, that our 20,000,000 acres of timothy and clover would increase the nitrogen content of the soil by 50 pounds per acre per annum; our 10,000,000 acres of alfalfa at the rate of 100 pounds of nitrogen per acre per annum; our 5,000,000 acres of velvet beans at the rate of 100 pounds of nitrogen per acre per annum; and our 10,000,000 of acres of miscellaneous legumes at the rate of 50 pounds of nitrogen per acre per annum. The total addition in these leguminous crops may be taken, therefore, as equivalent to 1,750,000 of tons of nitrogen.

Atmospheric precipitation in the form of rain, snow, hail, and dew adds to the soil small quantities of combined nitrogen varying from 2 to 3 to as much as 10 pounds per acre per annum. An allowance of 5 pounds of nitrogen per acre per annum would be well above the average for the 300,000,000 acres of arable land. The total would correspond to an equivalent of 750,000 tons of nitrogen. The amount of nitrogen fixed in the soil by Azotobacter and other non-symbiotic nitrogen-fixing organisms cannot be estimated with any degree of accuracy. For the 300,000,000 acres of arable land it may be equivalent to a minimum of 500,000 tons and a maximum of 1,500,000 tons of nitrogen. The additions in the form of commercial fertilizers would be equivalent to about 200,000 tons of nitrogen.

It seems, therefore, that the nitrogen compounds added to our arable land in the form of animal manures, leguminous green manures

and residues, the body substances of non-symbiotic nitrogen-fixing organisms, ammonia and nitric acid in atmospheric precipitation, and nitrate, ammonia, and organic nitrogen in commercial fertilizers represent an equivalent of five to six millions of tons of nitrogen. This leaves a net deficit of possibly three to four millions of tons of nitrogen for the 300,000,000 acres of arable land. The net loss is equivalent, therefore, to fifteen to twenty millions tons of sulfate of ammonia.

3. The losses of soil nitrogen are greatest in the regions of limited rainfall and of high summer temperatures, such as the northern Great Plains States. Under the conditions prevailing in this region, much of the nitrogen lost is due to the destructive decomposition of organic matter with the evolution of elementary nitrogen. Very intensive losses occur in the Southern States on account of the long open season, the relatively rapid oxidation of organic matter in the soil, and the leaching out of the nitrates formed. Very serious losses of soil nitrogen also take place in the Central States, largely on account of the faulty rotations in vogue and the failure to maintain a suitable soil reaction for the growing of legumes.

THE FIXATION OF AIR NITROGEN.

Fertilizer nitrogen is at best only a supplement to nitrogen derived from the soil itself. Every effort should be made to utilize crop residues and green manures or other natural resources of nitrogen, in order to decrease, in so far as it may be practicable and profitable, the need for the purchase of nitrogen in mineral products. When that point is reached the sources of commercial nitrogen should be drawn upon to insure maximum returns under any given conditions

Among the more common and effective methods for increasing the supply of nitrogen in the soil may be included the provision for an increased acreage of legumes and such shortening of our crop rotations as would make legumes relatively more prominent. Of late years there has been a notable expansion in the acreage of velvet beans, soybeans, peanuts, alfalfa, and sweet clover. The acreage of these and other legumes should be increased still further. By such expansion we should make certain of increased additions of nitrogen running into the hundreds of thousands of tons.

Recognizing the striking differences that exist in the ability of different legumes to assimilate atmospheric nitrogen, we should make an effort to grow such legumes as would, without prejudice to the other interests of the farmer, show the greatest degree of efficiency in fixing atmospheric nitrogen.

By way of illustration, one could refer here to the more pronounced ability of soybeans as compared with cowpeas in assimilating air nitrogen. Grown under the same conditions, the air-dry matter of soybean hay may contain 5 percent of nitrogen as compared with cowpea hay containing only 3 percent of nitrogen. These differences are inherent in the crops themselves, but there are lesser and yet important differences within different strains and varieties of the same crop. Hence, a splendid opportunity exists for improving our cultivated leguminous crops by selection and breeding, such improvement to lay stress on increasing the nitrogen-gathering power of the crops in question.

The fixation of nitrogen by leguminous crops, as well as by Azotobacter and other bacteria active in the soil itself, bears a direct and important relation to the chemical and physical nature of the soil. The reaction of the latter, the nature of the soil solution, the circulation of air, the water supply, and the quality and quantity of the organic matter all affect the activities of soil microorganisms and determine the extent of nitrogen fixation. There is room for a more systematic study of our cultivated soils for the purpose of enabling us to make these the most satisfactory culture media for nitrogen fixation. There is also room for improvement in the character of the microorganisms on which we depend for the assimilation of air nitrogen. It has been known for a long time that bacteria derived from different soils show more or less marked differences in their ability to assimilate elementary nitrogen. It would be reasonable to assume that, by careful selection, types of nitrogen-fixing bacteria might be developed that would be decidedly more efficient than most of those present in our cultivated soils.

As a supplement to the methods employed for increasing the fixation of atmospheric nitrogen by microorganisms alone, or by microorganisms acting in association with higher plants, the conservation of manure and soil nitrogen should receive very earnest consideration. The vast losses of soil nitrogen already referred to in this paper could be materially lessened by more adequately protecting our cultivated soils against leaching and surface washing. The enormous quantities of nitrates carried away in the surface drainage of the humid regions of the United States could, to a very substantial extent, be retained for future use by a more systematic covering of the land when the main crops are not growing. There is hardly need to more than mention the inexcusable losses of soluble nitrogen compounds from the manure of our domestic animals. The losses which

occur in farmyard manure on account of leaching, the escape into the air of ammonia and of free nitrogen, and the transformation of relatively available into unavailable nitrogen compounds through bacterial action are, to a great extent, preventable. The more thoro conservation of this nitrogen would substantially decrease the need for the purchase of nitrogen in commercial fertilizers.

After the so-called home resources of nitrogen are utilized to the fullest extent, there will still be ample opportunity for further and profitable increase in crop yields thru the use of manufactured nitrogenous fertilizers. Students of soil fertility in this country and abroad are generally agreed that, under more intensive methods of production, the increased use of nitrogenous fertilizers is a means for increasing profits in so far as plant food is at all a limiting factor in production. Of late years, there has been a remarkable expansion in the manufacture of so-called technically fixed nitrogen products. The stimulus of military necessity led to an amazing increase in the production of synthetic ammonia and of cyanamid in Germany. It is stated on good authority that the German plants have a capacity equivalent to 500,000 tons of fixed nitrogen per annum. The cyanamid plants have a capacity of 300,000 tons, while those using the Haber process have a capacity of 200,000 tons per annum. Of course, the actual production falls very far short of the present capacity. The existing difficulties as to labor, transportation, and fuel supply may not permit the fixation of more than 100,000 tons of atmospheric nitrogen at the German plants during the year 1919. Nevertheless, even under present abnormal conditions, technically fixed nitrogen is playing an important rôle in meeting the needs of agricultural production. Within a very few years the world capacity for technically fixed nitrogen may be equivalent to 1,000,000 tons of nitrogen or 5,000,000 tons of sulfate of ammonia. There is almost no limit to the kinds of fixed nitrogen products which may be manufactured for agricultural uses. Among the products already produced on a large scale or in an experimental way may be mentioned nitrates, such as potassium, ammonium, and sodium nitrate; ammonium salts, including sulfate, nitrate, chloride, phosphate, and bicarbonate; double salts, as potassium ammonium nitrate and sodium ammonium nitrate; and urea or derivatives like urea nitrate, urea calcium nitrate, urea superphosphate, etc. From the standpoint of quantity, cyanamid is, no doubt, the most important of the fixed nitrogen products. It has been successfully used as a fertilizer in Europe and in the United States. It has, however, certain limita-

tions which make it unpopular among the farmers, and it is rather generally agreed that its greatest value will lie in its serving as a source of secondary products rather than in supplying directly combined nitrogen for crop production. It is well known that cyanamid, when steamed under pressure, will readily give up its nitrogen as ammonia. The ammonia thus produced can be utilized for the making of different ammonium salts or for oxidation to nitric acid.

Aside from cyanamid, large quantities of calcium nitrate and of ammonium nitrate are now being manufactured. The production of calcium nitrate is practically limited to Norway. In 1918, about 61,000 tons of calcium nitrate were produced in that country. Nearly all of this was consumed in Norway for agricultural purposes; only a small proportion was exported. There is adequate experimental evidence to show that calcium nitrate is a very satisfactory nitrogenous fertilizer. Unfortunately, however, it is distinctly hygroscopic and difficult to apply thru fertilizer distributors. A granulated calcium nitrate is now being made in Norway which, in part, overcomes this objection. The farmers of Norway seem to be able to use it with much satisfaction to themselves, but, on the whole, the material is too hygroscopic for extensive use in other countries. Ammonium nitrate is also a satisfactory source of nitrogen when considered from the crop standpoint. It is, however, hygroscopic and, for this reason, objectionable. Farmers are also afraid of it because of its tendency to catch fire under certain conditions of storage. When used in the row it is apt to cause a very concentrated soil solution, with undesirable effects on germinating seed or young plants. In the case of cyanamid, interference with germination, more or less permanent injury to growing vegetation with which it is brought in contact, and injury to men and animals engaged in its distribution create serious objection to its extensive use in agriculture. The secondary products which will be developed from cyanamid, in order to be acceptable, will have to be free from the objections just noted.

THE POSSIBLE USE OF NITROGEN FERTILIZERS.

The more intensive use of nitrogenous fertilizers is essentially a problem in economics. It is obvious that, for crops of low commercial value, nitrogenous fertilizers, if used at all, can be used in limited amounts only. European as well as American experience seems to indicate that, with adequate rainfall and in the presence of adequate quantities of other plant-food constituents, supplemental applications of commercial nitrogen equivalent to 15 to 25 pounds per acre may

be profitable. Employed for crops of high commercial value the corresponding applications would be much larger, viz., 50 to 75 pounds per acre. A careful survey of the situation would show that for the 37,000,000 acres of cotton in the cotton belt nitrogenous fertilizers could be used effectively for supplementing the soil resources. A large part of the cottonseed meal now used as a source of nitrogen for the cotton crop should be replaced by nitrogen in mineral salts. This would not only lead to an increase in yield, but would also conserve large quantities of cottonseed meal which should be employed in the feeding of live stock. Similarly, in the case of the 46,000,000 acres of corn in the Southern States, at least 20,000,000 acres would respond to supplemental applications of nitrogen. In the Central States there are 6,000,000 acres of wheat, 20,000,000 acres of corn, 10,000,000 acres of oats, and 10,000,000 of grass that will respond to nitrogen treatment. In the North Atlantic States there are 11,000,000 acres of grass, 3,000,000 acres of corn, 2,000,000 acres of wheat, 3,000,000 acres of oats, and 1,000,000 acres of potatoes that will similarly respond to applications of nitrogenous fertilizers. All told, the increasing cost of labor and the increasing values of cultivated land will compel more intensive methods of production and lead us to revise our fertilizer practices in order that the average acre, as well as the average farm worker, may be made more efficient in the production of human food.

THE NEED OF RESEARCH AND DEMONSTRATION.

The use of the technically manufactured nitrogenous fertilizers will be affected by soil, plant, and climatic conditions. The nature of the soil itself must determine the type of nitrogenous fertilizer which is likely to prove most advantageous. In certain soils ammonium salts are to be preferred, while in other soils nitrates would be by far the most satisfactory source of available nitrogen. The chemical and mechanical conditions of the soil, the content of organic matter, and its reaction must determine the amounts and kinds of nitrogenous fertilizers that would give the most profitable returns. Over a large section of the United States the soils are decidedly basic in character. This is particularly true of the arid and semiarid regions. Where danger exists of the accumulation of black alkali, sodium nitrate is a far less satisfactory source of nitrogen than ammonium salts. On the other hand, soils distinctly acid in character are much less suitable for the use of ammonium salts than they are for the use of nitrates. It is also recognized that the ability of the soil to retain

fertilizing materials or to lose these when the rainfall is large is a varying and important factor in establishing fertilizer practice.

In the use of technically fixed nitrogenous fertilizers urea or other organic compounds may at times possess advantages that are not possessed by ammonium salts or nitrates. The farmers in the Old World have very decided preferences as to the source of nitrogen for their crops. Farmers on the continent of Europe and in Great Britain seem to feel that ammonium sulfate is much more satisfactory than sodium nitrate for the growing of potatoes. On the other hand, they feel that, for the growing of sugar beets and mangolds, sodium nitrate is to be preferred. They also recognize that, for early vegetables and for cereals and grasses that need stimulating early in the spring, nitrates are much more effective than ammonium salts. Farmers in the United States who have had experience in the use of nitrogenous fertilizers have often reached the same conclusion. It is hardly necessary to go into further detail concerning the points just noted. There scarcely need be any difference of opinion as to the desirability of further fundamental research on the use of concentrated nitrogen salts in American agriculture. A broad foundation must be established in which the factors of soil, climate, crop, and the nitrogenous fertilizers themselves would be assigned the proper place. Also from the economic standpoint there is need of careful study as bearing on types of farming, the cost of crop production, the value of the products and the skill and intelligence of the farmer. It will be found in the carrying on of such economic studies that the methods of application will prove to be a factor of considerable significance.

Much valuable information has already been accumulated by American investigators on the importance of our different nitrogenous manures and fertilizers for increasing production. The action of these manures and fertilizers is not always clearly understood because of our failure to date to outline our studies on a broader foundation. The time is ripe for cooperation among soil investigators in the study of the entire problem as it relates to agricultural production in the United States and particularly as it relates to the use of technically fixed nitrogen products, whose future use is not only certain to be very large but whose composition and cost will play a prominent role in determining production and cost of human food.

THE WORDS PRODUCTIVITY, OR PRODUCTIVENESS, AND FERTILITY AS APPLIED TO AGRICULTURE.[1]

C. V. PIPER.

The word fertility (Latin *fertilitas,* from *ferro,* to bear) was originally used by the Romans when applied to agriculture with the meaning of fruitfulness, that is, productiveness in large measure. The original application of the words fertile and fertility was primarily to regions or areas that produce abundant crops, for example, a fertile valley.

The words productivity and productiveness come from the Latin *produco,* to lead forth or to bring forth. In Roman usage the verb was used with various different meanings, among them that of bringing forth young. Only after the Augustan age was the word used in reference to the raising of crops. Our English words productivity and productiveness had no exact equivalents that were in use by the Romans.

The word productivity has retained in agriculture practically unvaried meanings. In a potential sense it signifies the quality or qualities of a region which enable it to grow useful crops, and in an actual sense productivity is the measure of the yields of a region as expressed in such units as pounds, bushels, tons, etc. The agricultural productivity of any region is conditioned on four series of factors, the climate, the soil, the adapted crop plants, and the adequacy of cultivation. The highest productivity exists where all four of these conditions are associated.

The word fertility in modern times has tended to become more and more restricted to the conception of soil fertility, thus excluding the other potent factors that make for productivity. In the restriction of the word fertility to this idea of soil fertility, various theories as to the nature of soil fertility have been advanced consecutively, namely, (1) that it is due to humus or vegetable matter; (2) that it is mainly a matter of physical condition or tilth; (3) that its basis is the amount and availability of certain chemical substances and especially com-

[1] Prepared as "Contribution to Agronomic Terminology—5" by the chairman of the Committee on Agronomic Terminology, C. V. Piper, and read at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 12, 1919, by C. R. Ball.

pounds of nitrogen, phosphorus, and potash; and (4) that yields are restricted by the presence of injurious organisms or substances in the soil. So far as present evidence goes, there may be and probably is truth in all the theories, but no one of them alone can be accepted as fully explanatory of the phenomena.

Nevertheless, many writers who accept the third theory have restricted the meaning of the phrase soil fertility and even of the word fertility to the three so-called plant nutrients, nitrogen, phosphorus, and potash, and attempt to measure the degree of fertility by the relative amounts and solubility of these substances. Where the word fertility is used in this last sense its relation to productivity may be reduced to zero, as in very cold, very wet, or very dry regions. While there can be no doubt of the important relations of nitrogen, phosphorus, and potash in the soil to the growth of plants, it is generally admitted that no method of soil analysis yet devised will enable one to determine relative productivity, at least for the great majority of soils. Potential productivity may be measured as actual productivity in terms of pounds, bushels, or tons per acre. However, it will lead to absurdity if productivity in different regions is measured by the same crop or the same series of crops. The real measures of productivity are the useful crops of one kind or another that can be grown or are actually obtained in the region. To compare North Dakota and Georgia on the basis of either flax or cotton production is manifestly absurd.

In view of the fact that the word fertility is often used in agriculture in the narrow sense of soil fertility or even of one of the theories of soil fertility, as well as in its broader original meaning, it is an unsatisfactory and often ambiguous terms to use in technical publications. Productivity or productiveness, both in their potential and actual applications, are words whose clearness has not been impaired by the evolution of ideas, and therefore they should be employed in preference to the word fertility as used in its broad application.

A further advantage of this proposal is not unimportant. As before stated, the word fertile means productive in a high degree. Therefore, it approaches the absurd to speak of low fertility, moderate fertility, etc. Fortunately the words productivity and productiveness have in them no such meaning either actual or implied. It is therefore entirely proper to speak of low productivity, high productivity, etc.

AGRONOMIC AFFAIRS.

REPORT OF THE SECRETARY-TREASURER.

This report covers the period from January 1, 1919, to October 31, 1919, inclusive.

The decline in membership so noticeable in 1918 has extended in a somewhat modified form into 1919. The resignations and lapses from the nonpayment of dues are still excessive, but partly to counterbalance these losses there have been more subscriptions and new members added than last year. It begins to appear to the Secretary-Treasurer that the unusual conditions resulting from the war and the high cost of living, which have adversely affected many scientific societies, are passing and that The American Society of Agronomy is back again on a stable basis.

One matter which I wish especially to call to the attention of the membership is the favorable notice given to the Society in foreign countries. This is evidenced by the continually increasing subscriptions to the JOURNAL from foreign sources. Libraries of our own country, other than those of agricultural colleges and experiment stations which have hitherto made up the larger part of our subscription list, are more and more coming to recognize the merit of the Society and are not only subscribing for the JOURNAL, but are purchasing complete sets of the back numbers of the *Proceedings* and of the JOURNAL. This is a condition which should make us all justly proud and should spur us on to give still better service. Investigators with material to present to the agronomic profession can find no medium of communication where their papers will be more widely read at the present time and less likely to be buried from future investigators, than in the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY.

The Society started the year with a paid-up membership of 509. Since then, 52 new members have been added for 1919 and 2 for 1920, 16 have been reinstated, 1 has died, 25 resigned, and 80 have let their membership lapse for nonpayment of dues. This leaves the Society with a paid-up membership of 473. In addition to this membership, there are 105 subscribers to the JOURNAL, some of them for two or more copies.

A special effort was made to enlarge the membership by asking certain agronomists to solicit new members in their respective States. Several responded with a number of candidates for admission. It has been my experience that a formal request seldom gets a new member, but a personal appeal from a friend who is already a member is what is needed to increase our membership. In this connection I wish to commend the work of a number of agronomists who have helped much in the past in getting new members, especially W. C. Etheridge of Missouri, John H. Parker and L. A. Fitz of Kansas, L. H. Smith of Illinois, John R. Fain of Georgia, and J. F. Cox of Michigan. If all of the States were represented in the Society in proportion to their agronomic workers as are New York, Ohio, Georgia, Kansas, and Missouri, our membership would soon be considerably larger than it is now.

The Secretary-Treasurer wishes to apologize for numerous delays and some errors in conducting the business of the Society. Being employed in work which makes it necessary for him to be absent from his office for weeks and sometimes months at a time, such delays are unavoidable. The indulgence and good will evidenced by the members in spite of these shortcomings is highly appreciated.

FINANCIAL STATEMENT FROM JANUARY 1, 1919, TO OCTOBER 31, 1919.

Receipts.

Balance on hand from previous year			$ 565.00
Dues from members:			
413 members for 1919	at $2.50	$1,032.50	
1 member for 1919	at .50[a]	.50	
1 member for 1919	at 2.25[b]	2.25	
1 member for 1919	at 1.50[c]	1.50	
7 members for 1920	at 2.50	17.50	
3 members for 1920	at 1.00[d]	3 00	
6 members for 1918	at 2.50	15.00	
2 members for 1918	at .50	1.00	
51 new members for 1919	at 2.50	127 50	
1 new member for 1919	at 2.00[c]	2.00	
1 new member for 1920	at 2.50	2.50	
1 new member for 1920	at 2.00[e]	2.00	
7 local members (Washington, D. C., section)	at .50	3.50	
JOURNAL and *Proceedings*:			
52 subscriptions for 1919	at 2.50	130.00	
23 subscriptions for 1919	at 2.25[b]	51.75	
5 subscriptions for 1918	at 2.50	12.50	
1 subscription for 1918	at 2.25[b]	2.25	
2 subscriptions for 1920	at 2.50	5.00	
3 subscriptions for 1920	at 2.25[b]	6.75	
1 subscription for 1920	at 2.00	2.00	
Sale of volumes previous to 1919		228.03	
Sale of reprints		56.25	
Total receipts			$2,270.28

[a] Balance paid in 1918.
[b] Agent's commission deducted.
[c] One dollar still due to the Society.
[d] Advance credits.
[e] Fifty cents still due to the Society.

NOTE: There were 4 advance payments of dues for 1919 and dues of 2 new members for 1919 reported in 1918. Outstanding bills for JOURNAL and *Proceedings* amount to $18.45 and 18 subscriptions are in arrears for 1919.

Disbursements.

1919.			
Jan.	4.	Telegram	$ 0.64
Jan.	7.	Rent of lantern	10.00
Jan.	13.	Postage	40.00

Jan.	14.	Postage	2.61
Jan.	18.	Refund on overpayment on JOURNAL	1.35
Feb.	1.	Maurice Joyce Engraving Co.	18.57
Feb.	1.	Lewis M. Thayer, printing	13.25
Feb.	7.	The Colonial Press, printing	4.15
Feb.	15.	Maurice Joyce Engraving Co.	7.30
Feb.	15.	Lewis M. Thayer, printing	80.50
Feb.	27.	Postage	2.73
Mar.	8.	New Era Printing Co.	161.69
Mar.	8.	Maurice Joyce Engraving Co.	7.25
Mar.	25.	Postage	1.88
Mar.	29.	Maurice Joyce Engraving Co.	30.07
Apr.	23.	Postage	1.55
Apr.	25.	Postage	2.09
May	22.	Postage	2.50
May	15.	Maurice Joyce Engraving Co.	23.00
June	16.	Mary Burr, clerical services	22.00
June	16.	Mary Burr, postage, etc.	5.00
June	16.	Postage	3.00
July	22.	Postage	5.00
July	23.	New Era Printing Co.	583.73
Sept.	8.	New Era Printing Co.	665.51
Oct.	15.	Postage	9.00
Oct.	21.	The Colonial Press	4.28
Oct.	24.	Maurice Joyce Engraving Co.	10.03
Oct.	30.	Maurice Joyce Engraving Co.	4.30
Oct.	30.	Mary Burr, clerical services	5.50
Oct.	30.	Telegram	1.05
		Total disbursements	$1,742.26
		Balance on hand October 31, 1919	528.02
			$2,270.28

LYMAN CARRIER,
Secretary-Treasurer.

MINUTES OF THE TWELFTH ANNUAL MEETING.

CHICAGO, ILL., November 10–11, 1919.

First Session, Monday Afternoon, November 10.

The meeting was called to order by President J. G. Lipman. The following papers were presented:

1. Some Considerations of an Interspecific Cross of Medicago, by L. R. Waldron.

2. The Effect of Zinc in Soil Tests with Galvanized Pots, by S. D. Conner.

3. *a*. The Truefast Test for Sour Soils; *b*. Status of Lime in Soil Improvement, by Elmer O. Fippin.

4. Reduction of Nitrates Caused by Seed as a Possible Factor in Crop Production, by J. Davidson.

5. Cereal Investigations During the War, by Carleton R. Ball.

6. Federal Seed Grain Loans, by C. W. Warburton (read by title in the absence of the author).

Second Session, Monday Evening, November 10.

Mr. C. G. Williams, presiding.

7. Taxing the Air for Nitrates, by Dr. J. G. Lipman, President of the American Society of Agronomy.

At the close of this meeting those interested in teaching soils held an informal discussion on that subject

Third Session, Tuesday Morning, November 11.

8. Discussion: Teaching Farm Crops. Leaders, W. L. Burlison and E. G. Montgomery.

9. Correlation Between Length of Mother Head and Yield of Progeny in Wheat, by A. N. Hume.

10. Some Observations on the Behavior of Smooth and Bearded Wheat, by A. E. Grantham

Fourth Session, Tuesday Afternoon, November 11.

11. The Coefficient of Yield, by F. S. Spragg.

12. Discussion: Standardization of Agronomic Experiments. Leader, S. C. Salmon.

Business Meeting.

The report of the Secretary-Treasurer, as presented elsewhere in this issue, was read.

The Auditing Committee reported as follows:

REPORT OF AUDITING COMMITTEE.

We have audited and found correct the statement of receipts and disbursements of Lyman Carrier, Secretary-Treasurer of The American Society of Agronomy.

(Signed) L. E. CALL,
A. R. WHITSON,
Committee.

By vote of the Society, the report of the Secretary-Treasurer was approved.

The report of the Editor, as published elsewhere, was approved.

In lieu of a report by the Committee on Terminology, a brief paper on "The Words Productivity, or Productiveness, and Fertility as Applied to Agriculture," prepared by the chairman, C. V. Piper, was read by C. R. Ball. This paper is published elsewhere in this issue.

The report of the Committee on Varietal Nomenclature was read by the chairman, E. G. Montgomery This was approved on motion, and is printed elsewhere in this issue.

The Nominating Committee, consisting of George Roberts, *chairman,* E. G.

Montgomery, and C. R. Ball, reported the following nominations for officers of the Society for the year 1920:

President, F. S. Harris, Utah Agr. Expt. Sta.

First Vice-President, C. G. Williams, Ohio Agr. Expt. Sta.

Second Vice-President, H. W. Barre, South Carolina Agr. Expt. Sta.

Secretary-Treasurer, Lyman Carrier, U. S. Dept. of Agriculture.

Editor, C. W. Warburton, U. S. Dept. of Agriculture.

On motion, it was voted that the Secretary-Treasurer be instructed to cast the ballot of the Society for these nominees for officers of the Society for the year 1920.

On motion, it was voted that M. A. Carleton be made an honorary life member without dues, in recognition of his services in organizing the Society.

On motion, it was voted that the programs of the annual meetings be prepared by a committee consisting of the Secretary-Treasurer as chairman, and two others to be appointed by the President, one member to represent the farm crops and one to represent the soils interests. C. R. Ball and C. A. Mooers were appointed on this committee for 1920.

On motion, it was voted that the Executive Committee appoint a Board to serve in an advisory capacity to the Division of Biology and Agriculture of the National Research Council on matters affecting agronomists, this Board to consist of five members, each to serve five years. The first appointees are to be designated by lot to serve for one, two, three, four, and five years, respectively. The Chairman of the Board is to represent the American Society of Agronomy on the Division of Biology and Agriculture of the National Research Council The following were appointed by the Executive Committee on this Board:

C. V. Piper, *chairman,* to serve 5 years; J. G. Lipman, to serve 4 years: John W. Gilmore, to serve 3 years; L. E. Call, to serve 2 years; and C. A. Mooers, to serve 1 year.

On motion, it was voted that a committee of two be appointed by the President to draft suitable resolutions on the death of Dr Cyril G. Hopkins and that copies of these resolutions be transmitted to the bereaved family and to the University of Illinois and also printed in the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY. Dr. J. G. Lipman and Lyman Carrier were appointed on this committee.

On motion, it was voted that the Program Committee be instructed to make the programs of the annual meetings as far as feasible symposiums around a central theme.

On motion, it was voted that a series of resolutions introduced by E. O. Fippin regarding the calling of a national conference of persons interested in the use of lime in agriculture be referred to the Advisory Board on Agronomy previously mentioned, with power to act.

On motion, it was voted that the Editor and Secretary-Treasurer be authorized to admit advertising to the pages of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY.

On motion, the meeting adjourned.

REPORT OF THE COMMITTEE ON VARIETAL NOMENCLATURE.

It is now eight years since the Committee on Varietal Nomenclature was appointed. During this period, steady progress has been made. Classifications of three important cereals, oats, barley, and wheat, have been practically completed to a workable stage. Of secondary crops, the sorghums are fairly well classified, while cowpeas and soybeans have received considerable study and the basis laid for classifications.

During this period, the agronomists have shown an increasing interest in the matter and now generally recognize the need of a standardized nomenclature. This has been aided by the movement in many States toward seed certification or registration and the need for standardizing varieties Also, agronomists have come to realize that the enormous work on varietal testing which has been done in the past has given comparatively little satisfactory knowledge in regard to the adaptation of varieties, owing to the fact that the common names used have little meaning. Future work along this line should be on a sounder basis.

Three years ago (December, 1916) the Committee suggested that the Society should take some steps officially to recognize standard names and further provide some means by which new introductions might be correctly classified as to type and registered. For the classification and registration of new introductions two plans were suggested, viz.: (*a*) that the Society appoint a committee for the purpose or (*b*) that the United States Department of Agriculture be approached with a request that an office be established especially to look after the work. No definite progress, however, was made. This was due partly, at least, to the war situation which demanded the attention of every one to other problems.

In the general educational movement three steps were pointed out two years ago (December, 1917): (1) The agronomists must be interested and trained in the work; (2) farmers must be interested, to the point where they would make some demand for the use of standardized names; and (3) seedsmen should be asked to cooperate and use the standard names.

As a step in this direction the committee was authorized to open negotiations with officers of the American Seed Trade, to see what cooperation they might offer. Several approaches have been made to the seed trade. They appointed a committee on nomenclature, but it has failed to respond in any way. The indications are that the seed trade is not ready to cooperate as yet. This convinces the Committee that the agronomists must lead the way in the standardization of names and the improvement and introduction of standard varieties until the seed trade finds it to be "good business" to cooperate.

Recommendations.

In order to give the movement more definite direction the Committee wishes to make the following recommendations to the Society for consideration:

To disband the present committee and form a new committee of five to ten members on the standardization of varieties, this committee to formulate a

plan for the testing and comparison of the standard types and new introductions. The functions of the Committee would be to:

(1) Examine proposed classifications and adopt a satisfactory classification.

(2) Propose changes or modifications in classification as occasion required.

(3) Attempt to arrange with agronomists for the testing of all standard types wherever practical in order to determine their relative adaptation. In case of new introductions, it is expected that they would be tested against the best standard types for the region. For the purpose of testing types, the country would be divided into definite climatic or soil regions.

(4) Appoint a subcommittee to identify and properly classify for seedsmen or agronomists, either old varieties or new introductions.

(5) Take steps toward the proper registration and publication of new introductions.

To accomplish this last object it is believed that the first step would be to ask the Secretary of the United States Department of Agriculture ot one of the agricultural colleges to provide a central office for this purpose.

REPORT OF COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

In the last few years this committee has made a thoro survey to get a comprehensive view of the present status of field-plot experimentation, with special reference to methods employed by workers along this line. A bibliography and partial review of the literature of the subject has also been made. The information thus gained has been valuable. We have found out the various methods in practice and the views of many of the workers regarding the relative merits of different methods now employed in studying the same sort of problems involving the use of field plots both in soil fertility and crop improvement work.

In giving further consideration to the matter this year, the Committee has been at a loss to know what to do next. The problems of standardization are by no means simple and it is felt that the Society should proceed slowly in making specific recommendations or standing sponsor for particular methods until more information concerning the relative accuracy and practicability is available. At any rate, this Committee has not been able to arrive at any conclusions as to the best methods in any particular line. Comparative data are insufficient or entirely lacking. Different workers have obtained satisfactory results by different methods and no one can say which method is best. Much experimental work in comparing methods needs to be done before we can really say which methods are best and before this Society can be justified in adopting any particular standard procedure or in asking its members to follow any single practice as the best.

To what extent is may be desirable to unify methods is still an open question. The best information we have suggests that complete standardization will not be practicable nor desirable. New workers will bring new ideas and individuality must not be unduly suppressed for fear of defeating the purposes of our science. Many important discoveries have been accidental, developing as sidelights and due to different methods of procedure. An increasing number of workers is engaged in experimenting in methods and we must look to

the results of their work to point the way. Such experimentation should be undertaken wherever possible with the view to getting together a mass of data out of which at least a few fundamental standards may be formulated. A committee of this kind should be continued and its personnel should consist of men actively engaged in the study of methods.

ADDITIONS TO BIBLIOGRAPHY.

The following titles should be added to the bibliography of this subject published in the December, 1917, and December, 1918, issues of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY:

ARNY, A. C., and GARBER, R. J. Field technic in determining yields of plots of grain by the rod-row method. *In* Jour. Amer Soc. Agron., 11, no. 1, p. 33–47. 1919.

ARNY, A. C., and HAYES, H. K. Experiments in field technic in plat tests. *In* Jour. Agr. Research, 15, no. 4, p. 251–262 1918.

ARNY, A. C., and STEINMETZ, F. H. Field technic in determining yields of experimental plots by the square-yard method. *In* Jour. Amer. Soc. Agron., 11, no. 3, p. 81–106. 1919.

CARRIER, LYMAN. A reason for the contradictory results in corn experiments. *In* Jour. Amer. Soc. Agron., 11, no. 3, p. 106–113. 1919.

CHRISTENSEN, H. R Experiments in methods for determining the reaction of soils. *In* Soil Science, 4, no. 2, p. 115–178. 1917.

LOVE, H. H. The experimental error in field trials. *In* Jour. Amer. Soc. Agron., 11, no. 5, p. 212–216 1919.

MIYAKE, C. The experimental error in field trials and the effect on this error of various methods of sampling. *In* Ber. Ohara Inst. Landw. Forsch., 1, no. 1, p. 111–121. 1916.

WALLER, A. E., and THATCHER, L. E. Improved technic in preventing access of stray pollen. *In* Jour. Amer. Soc. Agron., 9, no. 4, p. 191–195. 1917.

Respectfully submitted,

A. T. WIANCKO,
F. S. HARRIS,
S. C. SALMON,
Committee.

REPORT OF THE EDITOR.

Altho the income of the Society from memberships was further curtailed because of the large number of lapses and resignations and there has been some further increase in the cost of publication, the annual volume of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY will equal in size that of 1918. Including the December number, the volume will contain 356 pages, as compared with 360 pages last year, 432 pages in 1917, and 400 pages in 1916. Not including the December number, which will contain nothing except the President's address, the reports of committees, and the minutes of the annual meeting, the current volume included 35 papers contributed by 37 authors, representing 16 States, the District of Columbia, and Canada. Next to the Federal Department of Agriculture, the leading source of contributions was the University of Minnesota, 8 papers having come from the former and 6 from the latter. The volume was illustrated with 10 plates and 14 text figures.

Again the editor has to offer his apologies to the Society for certain shortcomings which it has been impossible to avoid. Thru the greater part of the year he was far removed from the place of publication and from library facilities, so that there has been some delay in the handling of proof and of correspondence regarding manuscripts, and it has not always been possible to check or complete citations of literature. Thru the cooperation of the printers, practically every issue has appeared on time, however, and now that the emergency work in which he was engaged is practically completed better service can be given.

Beginning with the August number, an advance of some 35 to 40 percent in printing costs was effective. Until that time, no change had been made in the rates since the original contract was made in 1913, except that charge was made for the advanced cost of paper. A proposition to take over the publication of the JOURNAL has been made by another company and will be presented to the Society by the Secretary, but the Editor recommends the continuation of the present arrangement for reasons stated in a letter to the Secretary transmitting the proposition. The advanced cost of publication will result in a marked curtailment of the JOURNAL unless the membership is largely increased in 1920.

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1920

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DATES OF ISSUE.

Pages 1–44, January 20, 1920.
Pages 45–76, February 16, 1920.
Pages 77–116, March 21, 1920.
Pages 117–148, April 22, 1920.
Pages 149–184, May 20, 1920.
Pages 217–240, December 1, 1920.

ERRATA.

In Vol. 11, p. 335, l. 18, read "1,750,000 tons" instead of "1,750,-000,000 tons."

In Vol. 12, No. 1, cover, title of paper by John H. Parker should read "A Preliminary Study of the Inheritance of Rust Resistance in Oats."

In Vol. 12, p. 195, l. 13, read "in Lychnis (14)" instead of "in Lychnis (15)"

CONTENTS.

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 6-7. SEPTEMBER-OCTOBER.

No. 8-9. NOVEMBER-DECEMBER.

JOURNAL

OF THE

American Society of Agronomy

Vol. 12. · January, 1920. No. 1

PLANTING RATES AND SPACING FOR CORN UNDER SOUTHERN CONDITIONS.[1]

C. A. Mooers.

Statement of the Problem.

In Tennessee, as in other Southern States, a wide range of varieties of field corn is grown. Some are recognized as standard in the corn belt; for example, Reid Yellow Dent and Boone County White. Others are standard in the South, such as Hickory King and the prolifics—Albemarle, Cocke, Biggs, Mosby, etc. Varieties differ materially with regard not only to length of growing season but also to height of stalk and to foliage production. These differences are especially marked when the varieties are grown on rich land. On alluvial land at the University farm, Knoxville, Tenn., when Huffman grows 12 feet tall Leaming will reach a height of about 8 feet. It is not surprising, therefore, to find that on the same kind of land different varieties require different rates of planting in order to produce both the largest yield and the best quality of grain. Also, as has been pointed out previously,[2] varieties of similar length of season and habit of growth may differ appreciably in the rate of planting which gives best results.

A wide variation in productivity is found among Tennessee soils. On the same farm it is not uncommon to find uplands which produce

[1] Contribution from the Tennessee Agricultural Experiment Station, Knoxville, Tenn. Revision of a paper read at the eleventh annual meeting of the American Society of Agronomy, Baltimore, Md., January 7, 1919. Received for publication July 27, 1919.

[2] Mooers, C. A., Stand and soil fertility as factors in the testing of varieties of corn, Tenn. Agr. Expt. Sta. Bul. 89, p. 49. 1910.

only 20 bushels of corn per acre and lowlands which produce 50 bushels or more. Common experience has shown that these different soils should be planted at different rates and, as a matter of fact, the corn on rich land is planted relatively thick and on poor land relatively thin, the rate being determined in every case by the judgment of the grower. Tho experienced corn growers are probably not far wrong when planting a well-known variety on a well-known soil, a material difference of opinion frequently exists, as might be expected, regarding the proper stand under any given condition. At best it is a guess. Unfortunately, many men have poor judgment in the matter, as can be seen at the close of a favorable season, a too thick stand being often in evidence.

A reliable guide is therefore needed in order to determine, with some degree of accuracy better than a mere guess, the proper stand of corn with regard to both the productivity of the soil and the variety to be grown. In this connection the best rate of planting for silage is of interest, as is also the effect of variation in the grouping and spacing of a given number of plants.

The Rate-of-Planting Experiments and the Determination of the Varietal Factor.

THE EXPERIMENTAL RATES OF PLANTING.

In the varietal trials conducted in various parts of Tennessee, the varieties of corn have for several years been planted in three blocks, each at a different rate. On the rich bottom land at the Knoxville station the rates have been 6,000, 8,000, and 10,000 plants per acre. On upland of good quality the rates have been 4,200, 5,400, and 6,600 plants. At the Jackson station in West Tennessee and in the Middle Tennessee experiments the rates have been 3,000, 4,200, and 5,400 plants. Soils differing considerably in productivity have been used, but in general the yields have been good, ranging from 30 to 80 bushels per acre. However, some experiments have been made on poor land, which under average conditions produced less than 30 bushels per acre. Data have been obtained which bear on the problem of the proper stand for each of a number of varieties of corn under various degrees of productiveness. The question then arose as to the possibility of assembling these data in such a way as to make the results of general application under similar climatic conditions. Hickory King, as a rule, yielded most in the rich-land experiments when planted at the 10,000 rate and in the Jackson experiments at either the 4,200 or 5,400 rate. But how were the results to be placed on a

simple basis which would allow the two series to be compared and perhaps lead to their application elsewhere?

RESULTS OBTAINED WITH HICKORY KING CORN.

The results obtained with Hickory King corn will be taken as an example of the methods followed with other varieties. Table I

TABLE I.—*Yields in bushels per acre of Hickory King corn at various rates of planting, with average weights of grain per plant.*

Location.	Year.	Rate of planting.						Selected rate.	
		6,000 plants.		8,000 plants.		10,000 plants.			
		Yield per acre.	Yield per plant.	Yield per acre.	Yield per plant.	Yield per acre.	Yield per plant.	No. of plants.	Yield per plant.
		Bu.	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*		*Lb.*
Knoxville, bottom land	1906[a]	64.1	0.60	81.1	0.57	89.9	0.50	10,000	0.50
	1906[b]	37.4	0.35	44.7	0.31	64.4	0.36	10,000	0.36
	1907[a]	49.2	0.46	53.5	0.37	60.0	0.34	10,000	0.34
	1907[b]	68.5	0.64	76.0	0.53	72.8	0.41	9,000	0.46
	1908	42.8	0.40	59.5	0.42	58.4	0.33	9,000	0.37
	1909	64.3	0.60	65.5	0.46	70.7	0.40	9,000	0.42
	1910	50.4	0.47	62.1	0.43	76.1	0.43	10,000	0.43
	1911	66.4	0.62	76.0	0.53	76.0	0.43	9,000	0.47
	1912	68.9	0.64	72.0	0.50	75.0	0.42	9,000	0.46
	1913	42.9	0.40	47.1	0.33	60.0	0.34	10,000	0.34
	1914	55.2	0.52	55.2	0.39	49.9	0.28	7,000	0.44
	1915	72.9	0.68	67.1	0.47	81.4	0.46	10,000	0.46
Average	....	56.9	0.53	63.3	0.44	69.6	0.39	9,333	0.42
		4,200 plants.		5,400 plants.		6,600 plants.			
Knoxville, upland....	1914	39.9	0.53	49.0	0.51	52.7	0.45	6,000	0.48
	1915	35.3	0.47	37.2	0.39	37.2	0.32	4,800	0.43
	1916	34.0	0.45	46.0	0.48	42.0	0.36	6,000	0.41
Average..........	....	36.4	0.48	44.1	0.46	44.0	0.38	5,600	0.44
		3,000 plants.		4,200 plants		5,400 plants.			
Jackson...	1910	41.5	0.74	43.3	0.58	43.3	0.45	4,800	0.51
	1911	21.9	0.41	30.2	0.40	23.1	0.24	4,200	0.40
	1912	36.0	0.67	41.1	0.55	45.6	0.47	4,800	0.51
	1913	34.5	0.64	41.6	0.55	39.6	0.41	4,800	0.47
	1915	36.8	0.69	49.1	0.65	50.7	0.53	4,800	0.58
	1916	34.0	0.63	48.8	0.65	52.7	0.55	4,800	0.59
Average..........	......	34.1	0.63	42.4	0.56	42.5	0.44	4,700	0.51
McMinnville........	1916	26.4	0.49	35.0	0.47	35.7	0.37	4,800	0.41
Tullahoma..........	1917	37.9	0.71	37.6	0.50	43.5	0.45	5,400	0.45
McMinnville........	1917	39.7	0.74	36.8	0.49	39.6	0.41	4,800	0.46
Algood.............	1918	44.6	0.83	43.7	0.58	42.8	0.44	4,800	0.51
Crossville..........	1918	25.7	0.48	25.7	0.34	25.7	0.27	3,600	0.40
Average..........	......	34.9	0.65	35.8	0.48	37.5	0.39	4,680	0.45

[a] Early planting. [b] Late planting.

shows the yields of grain in 12 trials on bottom land and in 3 trials on upland at the Knoxville station, in 6 trials at the Jackson station, and in 5 trials in Middle Tennessee.[8] Along with every yield is given the average weight of grain per plant. In all trials only one plat, which consisted of two 3-foot rows 60.5 feet long, or one one-hundred-and-twentieth of an acre, was used for each rate of planting, but the location of the plats was changed from year to year.

Relation Between Yield per Acre and Weight of Grain per Plant.

In the bottom-land trials at Knoxville the yields are decidedly in favor of the 10,000 plants per acre, the average grain production from that rate being 69.6 bushels. The next highest average is 63.3 bushels, from the 8,000 rate, and the lowest is 56.9 bushels, from the 6,000 rate. The weight of grain per plant is in the reverse order, the average being 0.39 pound from the 10,000 rate, 0.44 pound from the 8,000 rate, and 0.53 pound from the 6,000 rate.

In the upland series, the average yield at both the 5,400 and 6,600 rates was practically the same. The average weights of grain per plant were 0.48 pound at the 4,200 rate, 0.46 pound at the 5,400 rate, and 0.38 pound at the 6,600 rate.

In the seven years' trial at the Jackson station the 4,200 and 5,400 rates were tied for first place, with an average of 42.5 bushels of grain per acre, while the yield at the 3,000 rate was only 34.1 bushels. The average weights of grain per plant were 0.63 pound from the 3,000 rate, 0.56 pound from the 4,200 rate, and 0.44 pound from the 5,400 rate.

In the Middle Tenessee trials the highest average yield was from the 5,400 rate, with 37.5 bushels per acre and 0.39 pound of grain per plant. The next highest yield was from the 4,200 rate, with an average of 35.8 bushels per acre and 0.48 pound of grain per plant. The lowest yield was from the 3,000 rate, which produced 34.9 bushels per acre, with an average of 0.65 pound of grain per plant.

Taking the four series as a whole, it is evident that where the stand was thin so that the average weight of grain per plant was from 0.46 to 0.65 pound, the yield per acre was appreciably less than where the stand was so thick that only 0.38 to 0.46 pound of grain was produced per plant. In other words, the data indicate the conclusion that where Hickory King is planted at such a rate that the average

[8] Similar data relative to experiments with other varieties were submitted to the editors, but are not presented here because of the expense of printing. The data are summarized in Table 2.

weight of grain per plant is 0.38 to 0.46 pound the stand may be considered as approximately right for the soil and season.

Inspection of the results shows that the best number of plants per acre varies appreciably with the season. If the best rate, from a conservative point of view, is selected for each season and the weight of grain per plant is obtained, will not the average arrived at in this way be more closely correlated with the largest yield than the averages previously discussed? Believing this to be true, the writer has entered these data in the last two columns of Table 1 under the heading of "Selected rate."

In the selection of this rate and in the calculation of the weight of grain per plant to go with it in Table 1 and in similar data for other varieties, use was made of the following rules:

1. The highest yield determined the rate and was used as the basis of calculation unless the next highest was near enough to be considered as a duplicate.

2. When two rates give rise to duplicate yields, the average of the two rates was taken along with the average of the two yields for the calculation of the factor. Duplicate yields are delimited as follows:

a. Up to 40 bushels per acre, two yields were considered as duplicates if the difference was not more than 4 bushels.

b. For yields from 40 to 60 bushels, two yields were considered as duplicates if the difference between them was not greater than 10 percent of the higher yield.

c. With one or both yields greater than 60 bushels, two yields were considered duplicates if the difference between them was not greater than 6 bushels.

3. When the yields either of all three or of the lowest and highest rates were within the limits as given under paragraph 2, the two highest rates of planting were averaged if the yields were above the point of gravity, as determined by the medium rate of planting and the application of the finally accepted factor,[4] or standard weight of grain per stalk for the variety in question. With yields below the point of gravity, the two lowest rates are to be used. In either case the two highest yields were averaged as a basis for the calculation of the weight of grain per plant. This involves a "cut and try" method of procedure, but only for the small number of doubtful cases.

Continuing with Hickory King as an example, the highest yield

[4] The word "factor" is here used in its mathematical sense of a number entering into an equation to form a product. It is used as a substitute for the expression, "standard weight of grain per stalk."

for the early-planted crop of 1906 in the bottom-land series was 89.9 bushels at the 10,000 rate and, as the next highest yield could not be considered as a duplicate, the selected or probably best rate was 10,000 and the average weight of grain per stalk, 0.50 pound. In the case of the late-planted crop of 1907, the 8,000 and 10,000 rates gave rise to duplicates, hence the average of the two rates was taken and the average of the two yields was used in the calculation of the grain per plant at the selected rate. In the upland series for 1915 the yields were, within the limit of error, the same for all three rates. The average of the two highest, 37.2 bushels, was taken as the yield, but the rate of 4,800, or the average of the two lowest, was taken as the selected rate, because it gave a weight of grain per stalk more in harmony with the varietal standard of 0.45 than either the 5,400 rate or an average of the 5,400 and 6,600 rates.

According to the averages of the selected rate, the best number of plants in the bottom-land experiments was 9,333 and the average weight of grain per plant was 0.42 pound. In the upland experiments the averages were 5,600 plants and 0.44 pound of grain. In the Jackson experiments the averages were 4,700 plants and 0.51 pound grain. In the Middle Tennessee experiments the averages were 4,680 plants and 0.45 pound of grain. Using the selected-rate calculations, the average weight of grain per plant for all trials is 0.45 pound, and this number is taken as the standard for Hickory King.

THE VARIETAL FACTOR.

The weight of grain per plant most in harmony with the best yield, as calculated by the method outlined, will be referred to as the factor for the variety in question. Table 2 gives a list of varieties with standard or finally accepted factors as worked out either in this way or with a slight modification, as explained later.

Average Expectancy Calculations.

The total number of trials made with Hickory King is 26, which may be considered a fair number for a safe average. However, with the exception of Albermarle Prolific the number of trials for any of the varieties reported in Table 2 is considerably below 26, ranging from 5 to 19, so that the actual average may not be the best guide obtainable from the data. For example, the factor for the 1908 crop of the Little Willis variety is 0.39, which is nearly 25 percent less than the lowest factor in the 8 other trials. The factor 0.39 is included in the average for the bottom-land series, but is omitted in

TABLE 2.—*Standard varietal factors, or average yields per plant producing the highest acre yields of corn.*

Variety.	Total number of trials.	Average factor obtained.	Average expectancy basis.	
			Number of trials averaged.	Factor selected as standard.
Albemarle Prolific	28	0.573	28	0.573
Batt Prolific	6	.567	6	.567
Boone County White	16	.480	16	.480
Cocke Prolific	16	.576	16	.576
Hastings Prolific	7	.630	6	.585
Hickory King	26	.448	26	.448
Hildreth	7	.546	5	.588
Huffman	19	.617	14	.644
Iowa Silvermine	10	.387	10	.387
Jarvis Golden Prolific	12	.538	12	.538
Kansas Sunflower	6	.458	5	.476
Leaming	7	.373	5	.408
Legal Tender	6	.462	6	.462
Lewis Prolific	17	.606	13	.542
Little Willis	9	.557	8	.578
Looney	11	.532	11	.532
McAuley	5	.428	4	.460
Marlboro Prolific	7	.496	4	.548
Mosby Prolific	6	.523	6	.523
Neal Paymaster	18	.588	15	.548
Reid Yellow Dent	17	.458	17	.458
Webb Improved Watson	12	.493	12	.493
Wild Goose	6	.523	6	.523
No. 182	13	.518	11	.496

the average expectancy calculation shown in Table 2. In a similar manner, factors which vary widely from the others in the same group are included in the series averages, but are omitted in the calculation of the average expectancy averages of Table 2. In all such cases the average expectancy is assumed to give the better figure. It may be noted that for 11 out of the 24 varieties for which standards are given in Table 2, the average expectancy factors are different from the actual average of all results. For the other 13 varieties no results were excluded, so that the actual average and the average expectancy average are the same.

FORMULA FOR THE CALCULATION OF THE PROPER STAND OF CORN.

The yield of grain per acre may be calculated by multiplying the number of plants by the average production per plant. The number of plants is therefore equal to the yield in pounds divided by the average weight of grain per plant. If the yield is given in bushels, the equation is as follows:

$$N = 56Y \div F,$$

where N stands for the number of plants per acre, Y the yield in bushels, and F the average weight in pounds of grain per plant, 56, of course, being the standard weight of a bushel of corn. If F, as the varietal factor, is worked out experimentally and the average yield or expectancy of a given field is known, the proper number of plants to be allowed is easily calculated. For example, if Hickory King, with an assumed factor of 0.448, is to be grown on land which in a fair season produces about 40 bushels per acre, how many plants should be allowed per acre?

$$N = 40 \times 56 \div 0.448,$$

$$40 \times 56 = 2{,}240,$$

$$2{,}240 \div 0.448 = 5{,}000 \text{ plants.}$$

As the majority of seasons are favorable to a fair crop the assumption is made that no one should plant for the exceptional crop, either good or bad. It is probable that no good farmer does so in practice. Land that in a fair or average season produces 40 bushels of corn per acre should be planted therefore with that yield in view and not for either the occasional partial or the occasional extra large crop. This 40-bushel rate of planting does not mean, however, that little or no more can be produced in the extra favorable season. Examination of Table 1 shows that average weights of 0.60 to 0.82 pound of grain per stalk are not uncommon. Therefore, a field planted for a 40-bushel expectancy may make, so far as the number of stalks is concerned, 50 to 70 or more bushels per acre. On the other hand, the man who plants 40-bushel land for a 60-bushel crop need not be surprised at a yield reduced appreciably during a normal season in both quantity and quality as compared with that obtainable with the proper, or 40-bushel, stand. Fortunately the expectancy is generally well known; that is, the farmer knows whether a given field will, in a fair season, produce in the neighborhood of 20, 30, 40 or more bushels to the acre. As a matter of fact, in practice he keeps this expectancy in mind, planting thick or thin, depending on his judgment regarding the capacity of the soil.

The uncertainty in the equation is the value to be given F. Is F a constant or, as seems highly probable from evidence given later, is it a variable, which may within certain limits approach a constant?

Effect of Variation in Season and in Productivity on the Varietal Factor.

If factors obtained under conditions of high yield show a constant difference from those obtained under conditions of low yield, the

formula as given is evidently incomplete. The subject could logically be considered under two heads: (1) Variation due to differences in season and (2) variation due to differences in soil productiveness.[5]

Under the former head a soil of constant high productiveness is required, a condition which is well met by the bottom-land series. To meet the requirements of the second head, constant seasons and variable soils would be required. As this condition was not obtainable, the data from the different localities are considered as a whole and with the understanding that several variables influence the results.

INFLUENCE OF VARIATION OF SEASON.

The bottom-land series, which was conducted on a strong, rich soil and which was continued for the longest time and with the largest number of varieties, gives some valuable data as to the effect of season on the varietal factor. Table 3 is arranged to show the factors obtained from different yields for 19 varieties. Owing to the limited data for any one variety, stress should be laid on the averages rather than on the results for a single variety. Two averages from each yield are given. One is the actual average and the other, or corrected average, was obtained from the actual by making allowance for dif-

FIG. 1. Curve showing effect of season on the varietal factor.

[5] As all the data were obtained under similar climatic conditions, no attempt is made to discuss the effect of climate.

ferences chargeable to the blank spaces which give rise to averages from different sets. This correction, which was in general of minor importance, was accurately made by making use of the average factors as obtained in the bottom-land series. Figure 1 shows the curve obtained by plotting the corrected averages as ordinates and the yields as abscissas.

TABLE 3.—*Influence of season on the varietal factor as shown on results on bottom land at Knoxville.*[a]

Variety.	Yield in bushels per acre.					
	40–49 (45).	50–59 (55).	60–69 (65).	70–79 (75).	80–89 (85).	90–99 (95).
Albemarle Prolific	0.37	0.46	[2]0.51	[4]0.53	[2]0.68	....
Batt Prolific	.43	[2].50	....	.56	.76	....
Boone County White	.34	.43	[4].43	[2].58	[3].49	....
Cocke Prolific	....	[3].50	[2].52	[2].61	.66	[3]0.69
Hickory King	....	[4].37	.36	[5].45	[2].48	..
Hildreth	....	..	[2].56	.56	[2].50	..
Huffman	....	[2].48	.48	[4].62	[3].53	[2].62
Iowa Silvermine	.32	[3].32	[2].42	[2].43	....	....
Kansas Sunflower	....	.37	.52	[2].44	.48	....
Leaming	.28	[3].34	.37	.49	.46	....
Legal Tender	.28	[3].30	.37	.49	.46	....
Lewis Prolific	.46	....	[2].58	.61	.71	....
Little Willis	....	.52	[2].51	[2].56	....	....
Looney	....	....	[2].49	[2].61	.56	....
McAuley	.30	[2].41	....	....	.50	....
Marlboro Prolific	[2].41	.47	....	[2].55	.53	.56
Neal Paymaster	....	.46	....	[2].63	.53	.75
Reid Yellow Dent	.33	.45	[2].47	[4].45	.47	....
Webb Improved Watson	....	....	[2].41	[4].50	.51	.53
Averages (1) actual	[11].352	[29].425	[27].467	[42].540	[24].548	[8].630
(2) corrected	.371	.434	.472	.535	.543	.569

[a] The number of trials averaged, where more than one, is indicated by the superior figures.

The lowest average factor, as corrected, is 0.371, obtained at the average yield of 45 bushels per acre; the factor at the 55-bushel average is 0.434; at the 65-bushel average, 0.472; at the 75-bushel average, 0.535; at the 85-bushel average, 0.543, and at the 95-bushel average, 0.569, or the highest of all. It is evident, therefore, that the amount of grain per plant increases with the favorableness of the season even when planted at the best rate for acre production. Attention is called to the fact that the average of the standard factors for these 19 varieties is 0.514, which is within 5 percent of the average of all the figures in Table 3.

INFLUENCE OF VARIATION IN SOIL PRODUCTIVENESS.

Factors Obtained in Different Localities.

Table 4 shows the varietal factors as obtained in different localities and Table 5 is a summary of the results of Table 4. From this summary it is evident that the Jackson series gave the highest factors, which average 11.17 percent more than those obtained in the bottom-land series. The Middle Tennessee series gave factors which on the average were only 0.6 percent less than the bottom-land results. The upland series gave factors which averaged 6.43 percent less than the bottom-land series.

TABLE 4.—*Varietal factors or yield of corn per plant as obtained in different localities.*

Variety.	Knoxville. Bottom land. Yield per acre.	Knoxville. Bottom land. Factor	Knoxville. Upland. Yield per acre.	Knoxville. Upland. Factor.	Jackson. Yield per acre.	Jackson. Factor.	Middle Tennessee Yield per acre.	Middle Tennessee Factor.
	Bu.		*Bu.*		*Bu.*		*Bu.*	
Albemarle Prolific	70.6	0.58	.....	...	42.3	0.65	41.0	0.46
Boone Co. White	63.9	.46			43.2	.54	. .	. ..
Cocke Prolific	67.4	.58	.	...	36.5	.56	. .	.
Hickory King	69.6	.42	44.1	0.44	42.5	.51	36.7	.45
Hildreth	71.4	.54	.	..	50.2	.57	. .	. .
Huffman	68.6	.57	....	....	45.8	.73	..	. . .
Iowa Silvermine	56.8	.37	. .	.	40.9	.46	28.7	.34
Lewis Prolific	67.5	.59	46.0	.50	45.5	.70	53.6	.48
Little Willis	62.4	.53	...	....	43.7	.59	. ..	... ..
Looney	67.3	.55	. ..	. .	40.1	.50	51.3	.55
Mosby Prolific	78.9	.44	. .	. .	45.8	.61	45.1	.53
Neal Paymaster	79.3	.62	54.2	.55	56.1	.59	45.1	.58
Reid Yellow Dent	66.6	.44	35.2	.42	40.1	.47	40.5	.52
Webb Improved Watson	70.6	48	...	....	37.0	.53	.....	.. .
Wild Goose	68.7	.55	45.0	.50	. .	.....	.....	.... .
No. 182	75.8	.46	47.4	.48	46.4	.58	43.5	.54

TABLE 5.—*Summary of data shown in Table 4.*

Locality.	Number of varieties averaged.	Yield per acre.	Factor.	Increase or decrease (—), as compared with bottom land factor.
		Bushels.		*Percent.*
Knoxville upland	6	45.3	0.480	— 6.43
Knoxville bottom land	6	71.3	.513	....
Jackson	15	43.7	.573	11.17
Knoxville bottom land	15	69.1	.509	....
Middle Tennessee	9	43.9	.494	— 0.60
Knoxville bottom land	9	70.3	.497	....

Locality Data Arranged on a Comparable Basis.

In order to get an accurate comparison between factors obtained under different soil conditions, not only must the same varieties be grown under the same climatic conditions, but also the range in the rates of planting must be of the same order. In the four series under consideration there were variations both in seasonal conditions and in the range of the rates of planting. The latter is difficult to gauge perfectly, at least where only three rates of planting are used. In the series under consideration the lowest factors were obtained in the upland series where the rates of planting were the highest for the yield. They were probably too high for the conditions. The opposite appears to have been the case in both the Jackson and the Middle Tennessee experiments, that is, the rates were low for the yields obtained and this may account, at least in part, for the relatively high factors in the Jackson series. The rates used in the bottom-land series seem to have been good for most varieties. In none of the series, however, do the rates appear to be seriously wrong, so that their average is considered to be at least reasonably satisfactory.

Based on the assumption that the differences between the series when regarded as a whole were due to inequalities in the ranges of the rates of planting, to the brevity of the experiments, etc., the results of both the Middle Tennessee and the Jackson series were raised and those of the upland series reduced to the basis of the bottom-land series. Table 6 gives the data from 15 varieties as thus prepared at 6-bushel intervals to show the effect of yield on the varietal factor. Figure 2 shows the curve obtained by plotting the corrected averages, which were obtained in the same way as for Table 3.

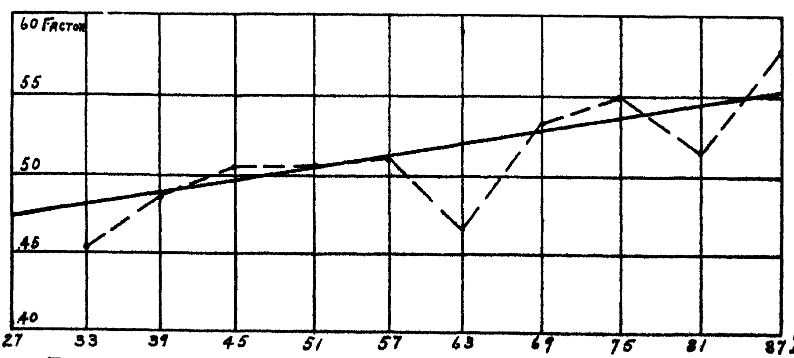


FIG. 2. Curve showing influence of soil productivity on the varietal factor. The broken line connects the points as found and the straight, solid line is the theoretical deduction.

TABLE 6.—*Influence of soil fertility on the varietal factor, a composite from all series when placed on a comparable basis.*[a]

Variety.	Yield in bushels per Acre.										
	24–29.	30–35.	36–41.	42–47.	48–53.	54–59.	60–65.	66–71.	72–77.	78–83.	84–89.
Albemarle Prolific...	....	^{4}0.49	^{4}0.48	^{5}0.56	0.58	^{2}0.55	^{3}0.55	.....	^{4}0.53	.....	^{2}0.68
Boone Co. White....	....	.....	.40	^{2}.43	^{2}.39	^{3}.50	^{2}.38	0.38	^{2}.58	^{2}0.49	.50
Cocke Prolific...	...	^{2}.60	.....	^{3}.58	.49	^{2}.50	.39	.64	.72	^{2}.55	...
Hickory King.....	0.37	^{2}.36	^{4}.41	^{4}.43	^{3}.47	^{4}.37	.36	.42	^{4}.46	.46	.50
Huffman ..	...	....	....	^{3}.54	^{2}.54	.48	^{2}.50	.66	^{4}.63	^{3}.55	.
Iowa Silver-mine .	.37	....	^{2}.32	.43	^{2}.32	...	^{2}.41	...	^{2}.43	.....	.
Jarvis Golden Prolific	..	...	^{2}.46	^{4}.48	^{2}.59	.66	^{3}.60	..	....	....	..
Lewis Prolific .	...	^{2}.49	.50	.75	^{5}.55	^{2}.64	^{3}.59	.70	.61	.....	.71
Little Willis	....	....	.58	^{2}.49	.55	.52	.39	.62	^{2}.56	....	...
Looney ..	...	.....	^{2}.56	^{3}.52	.61	..	^{2}.49	....	.47	^{2}.65	.
Mosby Prolific.. .	..	.39	..	^{2}.44	...	.49	...	...	.42	.46	...
Neal Paymaster	.47	.....	^{2}.46	^{3}.54	.58	^{4}.66	.64	^{2}.72	^{2}.70	.....	.53
Reid Yellow Dent	...	^{2}.40	^{3}.44	^{4}.43	.....	.45	.39	^{2}.48	^{3}.45	.47	.....
Webb Improved Watson ..	....	.	^{2}.46	.52	...	.....	.39	^{4}.43	.68	.49	.52
No. 182 ...	..	.41	.38	.44	^{6}.47	.47	...	.38	.47	..	.52
Averages:											
Actual ..	^{3}.403	^{14}.449	^{25}.471	^{39}.505	^{27}.512	^{23}.524	^{23}.468	^{15}.543	^{29}.551	^{13}.513	^{8}.566
Corrected.	.455	.452	.485	.505	.504	.511	.466	.533	.550	.515	.577

[a] Superior figures show number of trials averaged, when more than one.

As shown in Table 6, the greater part of the trials produced yields between 36 and 78 bushels per acre. Between these limits the corrected factors are perhaps as concordant as could be expected from the limited data, except for the very low factor of 0.466 in the 60–65-bushel column. The writer considers this column to be abnormal. However, taking the results as they stand, two interpretations seem possible; one, that they indicate a constant factor between the productivity limits of, say, 36 and 66 bushels, and the other that, with an increase of productivity, there is an increase in the factor as indicated in figure 2. The latter view is strengthened by inspection of the data given in Table 7, which gives the results of rate-of-planting trials under conditions of low yield.

Based on the course of the theoretical line shown in figure 2, the calculation was made that there was a variation of 0.0014 in the factor

for each bushel change in soil productivity. According to Table 2, the average of the standard factors for the 15 varieties is 0.521. This was found to coincide with a 64-bushel yield on the theoretical line. Taking the standard factors of Table 2 as standard for 64-bushel land, the change to be made for a soil of other productivity is easily calculated by means of the following formulas:

1. For land producing on the average more than 64 bushels per acre—

$$N = \frac{56Y}{F + (Y - 64).0014}.$$

2. For land producing on the average less than 64 bushels per acre—

$$N = \frac{56Y}{F - (64 - Y).0014}.$$

The Varietal Factor Under Poor-Land Conditions.

The data previously discussed include few obtained under poor-land conditions; that is, land producing about 25 bushels or less per acre. Table 7 gives the best data in the possession of the writer with regard to the effect of poor land on the varietal factor.

In the first section of Table 7 the average yield at each of the three rates is practically constant, and lower rates of planting were evidently needed in order to get the information desired. In the second section, the 3,200 rate gives the highest yield, but owing to the limited number of results little stress can be laid on the outcome. The comparatively slight effect of the variations in the rates of planting on the yield thruout the series is of special interest, because it shows that there can be a considerable range in the rate of planting on poor land without serious consequences.

According to Table 2, the average factor for the nine varieties represented in the first section of Table 7 is 0.52 and for the four varieties of the second section is 0.51. Either average is higher than that calculated for any rate of planting in Table 7 except for the 2,000 rate, which gave an inferior yield.

Altho the data indicate a reduction in the varietal factor for poor-land conditions, much more evidence is needed in order to find out the exact change that should be made. The writer considers it probable, however, that no land should be planted at a less rate than that calculated for a 25-bushel crop.

TABLE 7.—*Varietal factors under conditions of low yield.*

Variety.	Place.	Year.	Yield in bushels per acre.		
			3,000 rate.	4,200 rate.	5,400 rate.
Albemarle Prolific	Tullahoma	1916	16.8	20.3	22.5
Do.	Mayland	1918	18.3	19.7	18.5
Hickory King	Jackson	1914	23.2	20.8	13.2
Do.	Tullahoma	1916	24.6	21.0	24.6
Do.	Baxter	1918	16.3	17.1	19.7
Do.	Crossville	1918	25.7	25.7	25.7
Jarvis Golden Prolific	Tullahoma	1916	22.4	18.9	21.0
Do.	Baxter	1918	20.6	24.0	18.0
Do.	Mayland	1918	22.3	17.1	23.2
Lewis Prolific	Tullahoma	1916	21.0	21.0	24.6
Looney	Baxter	1918	18.8	19.7	18.0
Do.	Crossville	1918	25.7	30.0	29.1
Marlboro	Mayland	1918	17.5	21.0	17.1
Neal Paymaster	Tullahoma	1916	22.4	21.7	26.7
Do.	Baxter	1918	22.3	25.7	22.0
Reid Yellow Dent	Smithville	1912	19.1	23.4	24.8
No 182	Tullahoma	1916	19.6	16.8	21.0
Do.	Baxter	1918	21.4	26.6	24.0
Do.	Mayland	1918	18.8	21.0	20.6
Average yields			20.9	21.7	21.8
Factors from average yields			.39	.29	.23
			2,000 rate.	3,200 rate.	4,400 rate.
Albemarle Prolific	Knoxville	1918	23.2	27.6	27.6
Hickory King	McMinnville	1918	15.4	25.4	23.4
Looney	Do.	1918	25.0	25.7	23.6
No 182	Do.	1918	26 3	32.1	31.2
Average yields			22.5	27.7	26.5
Factors from average yields			.63	.48	.34

A TOO HIGH VERSUS A TOO LOW RATE OF PLANTING.

Two series covering much wider ranges of planting than those of previous years were carried out in the summer of 1918. One was conducted at the Jackson station, in West Tennessee, and the other at the Knoxville station, in East Tennessee. The data are given in Table 8 and the results are shown graphically in figure 3.

The soil selected at the Jackson station was poor, with an expectancy of only 20 or 25 bushels in a fair season. The season of 1918 was, however, decidedly unfavorable on account of dry weather. The soil at the Knoxville station was of high productivity, capable of producing 60 or 70 bushels per acre in a fair season.

The results from the two series agree in showing a rather rapid rise in yield with the increase in the number of plants, followed by a comparatively gradual decline after the maximum is reached. This

result is of interest as indicating that the margin of safety lies with a too high rather than a too low rate of planting.

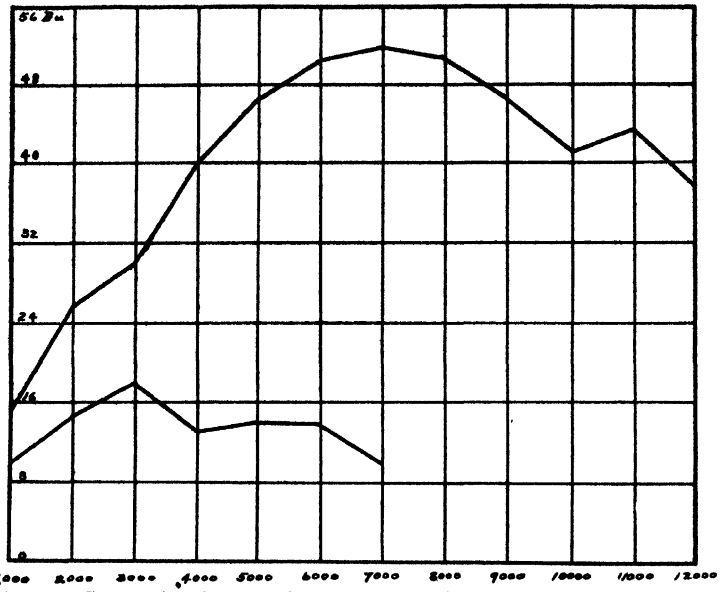


FIG. 3. Curve showing results of rate-of-planting experiments with corn as obtained at Jackson (lower curve) and at Knoxville (upper curve) in 1918.

TABLE 8.—*Results from two series of rate-of-planting experiments during the season of 1918.*

Plants per acre.	Yield per acre. Jackson station,[a] Grain, bushels.	Jackson station,[a] Stover, tons.	Knoxville station,[b] grain in bushels.
1,000	9.8	0.32	15.2
2,000	14.6	.43	25.7
3,000	17.8	.62	29.6
4,000	13.2	.59	40.0
5,000	14.2	.71	46.5
6,000	14.0	.80	50.5
7,000	9.9	.82	51.7
8,000			50.8
9,000			46.7
10,000			41.2
11,000	....	....	43.5
12,000	...	...	37.8

[a] The soil on which the corn was grown at Jackson was poor and the season very unfavorable. The different rates were planted in fortieth-acre plats replicated four times, except the 2,000 and 7,000 rates, which were replicated only three times.

[b] At Knoxville, the soil was good, but the season was below the average. All plats were duplicated.

RATE OF PLANTING FOR SILAGE.

Table 9 gives the total production of ear corn and stover in three series of rate-of-planting experiments. The yields were obtained by adding together the weights of stover when well cured in the shock and of ear corn when in a thoroly air-dry condition. In this table only those varieties were included which made their greatest average grain production at rates well below the maximum rate of planting.

TABLE 9.—*Yields per acre of combined ear corn and stover on a field-cured basis at different rates of planting.*

KNOXVILLE BOTTOM LAND.

Variety.	No. of years.	Yields in pounds per acre.			Best rate for grain yield.[a]
		6,000 plants.	8,000 plants.	10,000 plants.	
Albemarle Prolific	13	9,769	10,067	10,617	6,929
Cocke Prolific	11	9,983	9,826	10,456	6,601
Hildreth	5	9,666	10,480	10,329	6,847
Huffman	13	11,433	11,284	12,048	5,965
Legal Tender	5	8,043	9,109	9,390	7,745
Lewis Prolific	5	9,325	8,882	9,082	6,974
Little Willis	5	9,211	9,438	9,276	6,046
Looney	5	8,958	8,864	8,868	7,084
Average	7.8	9,549	9,744	10,008	6,774

KNOXVILLE UPLAND.

		4,200 plants.	5,400 plants.	6,600 plants.	
Hickory King	3	5,068	6,080	5,960	5,673
Jarvis Golden Prolific	3	5,799	6,022	5,981	4,705
Neal Paymaster	3	6,152	6,954	6,861	5,540
Wild Goose	3	6,086	6,570	6,050	4,818
Average	3	5,776	6,407	6,213	5,184

JACKSON.

		3,000 plants.	4,200 plants.	5,400 plants.	
Albemarle Prolific	8	6,320	6,515	5,969	4,134
Cocke Prolific	5	5,770	5,633	6,324	3,549
Hickory King	6	5,527	6,668	6,595	5,289
Huffman	6	8,872	9,640	10,422	3,983
Lewis Prolific	7	6,719	6,904	6,974	4,701
Little Willis	4	5,791	6,152	6,306	4,234
Webb Improved Watson	5	4,884	6,236	6,112	4,203
Average	5.9	6,269	6,821	6,958	4,299

[a] Calculated from selected factor.

In the bottom-land series are shown the yields of 8 varieties which were grown from 5 to 13 years each, with a general average of 7.8

years. The best average rate of planting for grain production for the 8 varieties was 6,774 stalks per acre. The average yields at all three rates of planting, however, are very close together. At the 8,000 rate, the total yield is only 2 percent more than at the 6,000 rate. At the 10,000 rate, which is an increase of 48 percent over the number of plants required for maximum grain production, the total crop was increased by less than 5 percent over that from the 6,000 rate and the calculated increase over the best rate for grain is less than 2 percent.

In the upland series with 4 varieties for a period of three years, the best average grain rate was 5,184 stalks per acre, or a little less than the medium, or 5,400 rate. The average yield of air-dry crop at the 5,400 rate is 6,407 pounds, which is 194 pounds more than was obtained at the highest rate of planting.

In the Jackson series, which included 7 varieties for an average period of 5.9 years, the best grain rate averaged 4,299 plants per acre. The average yield at the nearest rate of planting, the medium or 4,200 rate, was 6,821 pounds per acre. At the 6,600 rate of planting, with an increase of nearly 30 percent in the number of plants, the increased yield was only 137 pounds per acre.

The evidence as obtained in the three series agrees in that the planting which gives the largest grain yield lacks little of giving the largest total yield of ear corn and stover. In fact, the results are so close that the doubt is left whether increasing the number of stalks above that required for the maximum grain production will increase the crop as a whole. However, as there is no evidence of loss from a moderate increase in rate of planting, and as in common farm practice a thicker rate would be expected to result in a more complete occupation of the ground by reducing the number of gaps, an appreciable increase in the number of stalks per acre over that estimated for best grain production may be advisable for a silage crop.

The Spacing of Corn.

After the proper number of plants per acre has been determined, the question arises as to the effect on the yield both of the distance between rows and of the arrangement of plants in the row. Are wide-spaced rows as good as narrow? Does corn planted in check rows yield as well as corn planted in drills? Considerable data bearing on these questions have been obtained by different experiment stations, and the general conclusion has been reached that minor changes in arrangement, such as widening or narrowing the space

between the rows and planting in check rows or in drills, does not affect the yield, provided the number of plants per acre remains the same. There must always be limits, however, beyond which there is danger of decreased yield. The data presented in Tables 10 and 11 are given as an aid to the solution of the problem under conditions similar to those found in Tennessee.

THE NUMBER OF PLANTS PER HILL.

The data from experiments made in triplicate each year for five years on a soil of good fertility at the Knoxville station farm are given in Table 10. In these experiments the number of plants per hill varied from 1 to 3. The number of plants per acre in each case was 8,000, a number which is a little high for the fertility of the land.

TABLE 10.—*Yields of corn when planted in the hill at different rates, but with the same number of plants per acre.*[a]

Year.	Number of plants per hill.	Width of check row.	Yield per acre.	
			Grain.	Stover.
		Feet.	*Bushels.*	*Tons.*
1907	1	2.3 x 2.3	50.6	2.34
1908	1	2.3 x 2.3	42.6	1.58
1909	1	2.3 x 2.3	36.4	1.40
1910	1	2.3 x 2.3	47.2	1.52
1911	1	2.3 x 2.3	71.3	2.10
Average			49.6	1.79
1907	2	3.3 x 3.3	51.8	2.27
1908	2	3.3 x 3.3	45.6	1.77
1909	2	3.3 x 3.3	34.7	1.39
1910	2	3.3 x 3.3	47.2	1.44
1911	2	3.3 x 3.3	70.2	1.94
Average			49.9	1.76
1907	3	4 x 4	48.4	2.15
1908	3	4 x 4	40.2	1.60
1909	3	4 x 4	38.0	1.33
1910	3	4 x 4	45.0	1.40
1911	3	4 x 4	65.4	1.82
Average			47.4	1.66

[a] Experiments conducted in triplicate each year on fiftieth-acre plots.

The 5-year average yields are almost identical for the 1- and 2-plant stands. With the 3-plant stands, however, the yields average 2.2 bushels per acre less than with the 1-plant, and 2.5 bushels less than with the 2-plant. The difference is noteworthy for the reason that in four out of the five years the lowest yields of grain were obtained

from the 3-plant stands and that without exception the lowest production of stover was from this planting.

DISTANCE BETWEEN ROWS.

Table 11 gives the yields of corn when planted in 7-foot and in 3.5-foot rows, but with the same number of plants per acre in each case. The results of the two years' trials agree in that the yields of both grain and stover are materially less from the 7-foot than from the 3.5-foot rows. In the 1914 trials the average yield per acre from the 7-foot rows was 75 bushels of grain and 3.42 tons of stover. The 3.5-foot rows produced an average of 88.4 bushels of grain and 4.81 tons of stover, or an increase of 13.4 bushels of grain and 1.39 tons of stover. In 1915 both the upland and the rich alluvial soil gave similar results to those obtained in 1914, the average yield of the upland and alluvial soil experiments being 69.7 bushels of grain and 2.72 tons of stover from the 7-foot rows and 83.3 bushels of grain and 3.05 tons of stover from the 3.5-foot rows.

TABLE 11.—*Yields of corn when planted in 7-foot and in 3.5-foot rows.*

Year.	Variety.	Kind of soil.	Plot No.	Plants per acre.	Yields per acre. 7-ft. rows. Grain.	Yields per acre. 7-ft. rows. Stover.	Yields per acre. 3.5-ft. rows. Grain.	Yields per acre. 3.5-ft. rows. Stover.
					Bushels.	*Tons.*	*Bushels.*	*Tons.*
1914	Albemarle	Rich alluvial	1	8,000	92.1	4.30	..	...
	do	do	2	8,000	90.0	3.77		
	do	do	3	8,000	....	....	101.7	4.66
	Hickory King	do	4	7,000	65.3	3.45	. .	
	do	do	5	7,000	67.0	3.24		
	do	do	6	7,000	....	..	80.9	4.80
	do	do	7	7,000	67.6	2.44	....	....
	do	do	8	7,000	67.9	3.33	....	....
	do	do	9	7,000	.. ..	.. ...	82.6	4.98
			Average		75.0	3.42	88.4	4.81
1915	Hickory King	Upland	1	6,000	. .	. .	60.0	1.95
	do	do	2	6,000	53.8	2.73	....	....
	Albemarle	do	3	6,000	......	....	51.4	2.85
	do	do	4	6,000	44.8	1.49	....	....
	do	Rich alluvial	1	8,000	....	....	113.0	4.09
	do	do	2	8,000	90.9	3.57	....	....
	do	do	3	8,000	....	....	108.9	3.29
	do	do	4	8,000	89.2	3.10	....	....
			Average		69.7	2.72	83.3	3.05

GENERAL CONCLUSIONS FROM THE SPACING EXPERIMENTS.

The two series of experiments, one to determine the best number of plants per hill for check-row planting and the other to determine the effect of material differences in distance between rows, supplement each other. The former series showed that no decrease in yield came from the narrow rows, which spaced the plants at equal distances from each other. On the other hand, the latter series showed that the spaces between rows may easily be so wide as to reduce the yield. The general conclusion seems warranted, therefore, that the best results in practice will probably be obtained with a width of row which permits the satisfactory use of tillage implements but allows the determined number of plants to be as widely spaced as possible.

SUMMARY.

1. The rate of planting corn is of much practical importance in the South, but a definite rule is needed. Too thick planting is of common occurrence.

2. Different varieties require appreciably different rates of planting. In general the small and short-season varieties require thicker planting than the large, long-season varieties.

3. The experimental results indicate a close relationship between the best rate of planting for grain production and a definite yield of grain per plant. For example, the Hickory King variety was found to yield best when the rate of planting allowed the average plant to produce about 0.45 pound of grain.

4. To approximate the proper stand of corn a simple equation may be used, as follows:

$$N = \frac{56Y}{F}.$$

In this equation, N stands for the number of stalks per acre, Y for the expectancy, or approximate production in bushels per acre of the field in question under average seasonal conditions, and F is the standard varietal factor, or the average weight of grain per plant at the best rate of planting, as determined experimentally for the variety in question.

5. On land of high productiveness the average weight of grain per plant at the best rate of planting was found to vary from year to year with the nature of the season, so that the more favorable the season the greater was the weight. The standard varietal factor is practically the result obtained for the average of all seasons.

6. The data as obtained may be interpreted as indicating that a varietal factor is practically a constant between the 36-and 65-bushel limits of productivity. However, the weight of evidence indicates that as the productiveness of the soil changes a change should be made in the varietal factor. On the average for 15 varieties, this change was calculated to be 0.0014 per bushel change in expected yield. With this in view, the following formulas may be used in connection with the table of standard factors:

(1) For land producing on the average more than 64 bushels per acre—

$$N = \frac{56Y}{F + (Y - 64).0014}.$$

(2) For land producing on the average less than 64 bushels per acre—

$$N = \frac{56Y}{F - (64 - Y).0014}.$$

In addition the suggestion is made that no rate of planting should be less than that calculated for a 25-bushel crop.

7. The margin of safety appears to go with a too high rather than a too low rate of planting.

8. The results of three series of experiments agree in showing that the best rate of planting silage corn was little different from that which gave the highest yield of grain. In practice, however, a material increase seems warranted.

9. In the spacing experiments the conclusion was reached that the best results in practice will probably be obtained with a width of row which permits the satisfactory use of tillage implements, but allows the determined number of stalks to be as widely spaced as possible.

A PRELIMINARY STUDY OF THE INHERITANCE OF RUST RESISTANCE IN OATS.[1]

JOHN H. PARKER.

INTRODUCTION.

Having found that there are disease-resistant species or varieties in a given crop, the next problem often is one of hybridization. The literature of the subject contains many references to the discovery or production of disease-resistant varieties, but there are, in proportion, very few examples of the profitable or extensive culture of such varieties. This is largely due to the fact that most of them are so undesirable with regard to one or more other equally important characters that they cannot be generally and profitably grown. This is exactly the present condition of affairs in the case of rust-resistant oat varieties.

It has been shown (15)[2] that so far as cultivated varieties are concerned, resistance to crown rust exists almost exclusively in varieties of the red oat group (*Avena sterilis*). Resistance to stem rust is not to be found in any of the varieties of the red oat group so far tested, but does exist in some of the varieties of the common oat group (*Avena sativa*). Some of the red oats resistant to crown rust are well suited to culture in the Southern States where they are widely grown, but they are not adapted to the conditions of the Northern States. On the other hand, the white oats, certain varieties of which are resistant to stem rust, seem specially adapted to the northern half of the United States and are entirely unsuited to conditions in the South. These conditions make it highly desirable that some knowledge be gained of the manner of inheritance of the character, rust resistance. In fact, this is essential if the method of hybridization is to be intelligently and successfully used in producing

[1] Contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United State Department of Agriculture, Washington, D. C. Received for publication September 15, 1919.

The experiments here described were conducted at Cornell University. The work was under the supervision of Dr. H. H. Love, Professor of Plant Breeding, whose suggestions and assistance are gratefully acknowledged. Thanks are due Mr. W. I. Fisher for making the photographs used in the paper.

[2] Reference is made by numbers in parentheses to "Literature cited," page 37.

new varieties which are resistant to a given rust species, and are, in addition, adapted to local conditions and capable of producing a high yield of grain which will come up to market standards.

The preliminary work reported in the present paper was done in the attempt to determine the genetic behavior of the character, rust resistance, in a cross between resistant and susceptible oat varieties of the two groups mentioned above.

Historical Review.

No attempt will be made to review completely the literature of disease resistance, or even that of rust resistance in cereals. Orton (12, 13, 14) has succeeded in transferring the character, disease resistance, and has been able to obtain and fix races of hybrid progeny which combine this character inherited from one parent with others of commercial importance from the other parent. Norton (11), working on the control of asparagus rust, has achieved success thru using the method of hybridization, and the new rust-resistant race now is being grown commercially. Farrer (6, 7) has succeeded in producing wheat hybrids which are rust resistant, and at least one of them is now commonly grown in Australia. Evans (5) has recorded rather discouraging results, for he has found what seems to be a case of a hybrid between a resistant and a susceptible wheat acting as a bridging species. He was able, by culturing the rust on plants of the susceptible hybrid, to obtain spores which would infect the heretofore resistant parent, and which also increased the virulence of the infection on the susceptible parent. If these results should prove to be generally true, breeding for rust resistance in cereals would be of doubtful value. The work of Stakman and Piemeisel (17), however, has not strengthened the idea that bridging hosts are of great importance.

Stakman, Parker, and Piemeisel (18) have shown that susceptible hybrids of the F_1 and F_2 generations of crosses between resistant and susceptible wheats did not enable the rust cultured on them to cause normal infection on seedlings of the resistant parent, nor to infect the susceptible parent more virulently.

Biffen (1) crossed a wheat he classed as immune with a susceptible wheat and found that

> the F_1 plants were susceptible and that in the F_2 generation the proportions of badly to slightly attacked were in the ratio of 3 to 1. In the F_3 generation the relatively immune individuals bred true to this character, but the susceptible types taken as a class produced either all susceptible offspring or a mixture of susceptible and relatively immune plants.

In a second paper, Biffen (2) reports the results of further work and states that

> in counts made of F_2 plants from crosses between wheats immune from, and susceptible to, yellow rust, the ratio of 1 immune to 3 susceptible was again obtained. The F_3 generations of all these crosses were not studied, but in the F_2 there were indications of the existence of intermediate types. In the case of one cross between Rivet (immune) × Red King (susceptible) the extracted recessives only have been grown. These have maintained their immunity through the F_4 generation.

The experiments with black stem rust are reported to have been "not altogether successful," but from analogy with the cases already described and from the susceptibility of the F_1 generation, it would appear that the susceptibility to black rust is also a dominant character.

In a third paper, Biffen (3) has published an account of the continuation of these earlier studies. In this paper he reports that

> the plants of hybrid generations showed very varied degrees of susceptibility. Some were relatively slightly attacked, and between these extremes all degrees of susceptibility appeared to exist. In the work since 1907, where F_3 results were compared with the F_2, is has been found:
>
> 1. That the immune types of the F_2 generation breed true to that feature.
> 2. That some of the susceptible forms also breed true but others produce offspring showing segregation into susceptible and immune forms.
> 3. That plants of the "medium class" are not necessarily heterozygous.
> 4. Where segregation occurs, the sum total of immune and susceptible individuals is again in the ratio of 1 : 3. The actual numbers of the whole series were 276 and 849. 1125 (28125 : 84375)
>
> The results are those that might have been anticipated from those of the F_2 generation. They show, conclusively for this particular cross, that the varying degrees of susceptibility are not due to the effects of more than one "dose" of the factor concerned with the production of susceptibility.

Having rejected the multiple-factor hypothesis as an explanation for the wide range in susceptibility observed, Biffen gives it as his belief that the varying and probably constant degrees of susceptibility seen in F_2 and succeeding generation probably are due to the extreme ease with which the degree of susceptibility is altered by slight changes in the plant's metabolism. Biffen further asserts that "none of the cases examined up to the present time indicates that rust susceptibility itself is due to the existence of more than one factor."

Newman (9), in reporting on the work in cereal breeding at Svalof, gives the following account of the behavior of the character, rust resistance, in crosses:

> For example, from the crossing 0401 × 0705, both classified as grade 2 (moderately resistant), eight separate cultures were investigated during the bad rust year of 1904, and the differences observed in these plats were recorded as

exceedingly striking. The difference between the most susceptible culture and that which showed greatest resistance was much greater than the difference between the parent's themselves.

From the crossing 0319 × 0501 (both sorts of high resistance) there were produced a number of lines, some of which in F_3 proved much more susceptible than either parent.

Thus it may be seen that apparently new forms may arise from crossing between sorts which to all appearances are practically identical in regard to certain characters. The origin of these forms is due simply to peculiar grouping of definite units already in existence, and not to the acquisition of anything actually new. In other words, they constitute different gradations, a quantitative hereditary variation.

The conclusions (English translation) reached by Nilsson-Ehle (10) in his study of the resistance of wheats to yellow rust (*Puccinia glumarum*) at Svalof, Sweden, are as follows:

1. Segregation of rust resistance in crossing is always definitely present.
2. The segregations in these investigations have always been complex. There customarily result from the segregation new gradations of rust resistance approaching the parental gradations, and in the F_3 plats, transgressions more susceptible or more resistant than the parents, are readly shown to exist. Also, crosses between varieties of about the same or differing only slightly in rust resistance give, in their progenies, segregation with transgressive forms.
3. The complicated segregation and the production of segregates from the crossing of lines of about the same resistance is explained by the existence of several independent (multiple) Mendelian factors, which influence (determine) the rust. All data found to date agree with this hypothesis.
4. The heritable gradations of rust resistance exhibited by the different varieties and lines are not due to independently arisen variations, but to different combinations of a number of factors, whereby different combinations of factors may exhibit about the same outer resistance. Through different new combinations of factors, new gradations arise, after the crossing of varieties or lines differing or of nearly the same rust resistance.

Love (8) has called attention to the possibility, and perhaps the necessity, of using hybridization to obtain varieties of oats which shall be rust resistant, of good market quality, and of high yielding power.

Description of Varieties and of Material Used.

In the experimental studies here reported, pure lines of Burt and Sixty-Day oats and F_2 generation hybrid plants from a cross between these varieties comprised the material used.[3] The original cross was made by Doctor Love in the greenhouse at Cornell University during the winter of 1913–1914, and the F_1 generation plants were grown there by him the following winter, in connection with other studies of inheritance in oats.

[3] From the cultures of the Department of Plant Breeding at Cornell University.

The two parent varieties, Burt and Sixty-Day, are quite distinct in appearance, habit of growth, and particularly in the characters of the kernels. They represent different botanical groups, Burt usually being classified with the varieties derived from *Avena sterilis* and Sixty-Day being a variety of the *Avena sativa* group. Their origin, corresponding with that of the two botanical species, no doubt is different, and their present distribution consequently is not the same. Both are early spring varieties, and the districts to which they are adapted overlap to some extent. Thus in Kansas and Nebraska both varieties are successfully grown. In the southern and southeastern States, Burt is probably the best spring variety to grow.

Etheridge (4) gives a full description of Burt and Sixty-Day varieties.

Warburton (19) gives brief notes on Burt, Sixty-Day,[4] and Kherson oats, relating especially to their value as rust-escaping sorts.

Plumb (16) states that Burt is rather locally grown, not being known over a wide territory. It does well, generally, in Mississippi, Alabama, Georgia, South Carolina, and northern Florida. It is grown to some extent in northern Alabama, Georgia, South Carolina, and middle and eastern Tennessee.

The Burt oat is very similar to if not identical with Early Ripe and both were found to show resistance to crown rust. Because of this similarity in appearance and in reaction toward rust, an attempt was made to get some of the facts relating to the origin and history of the two varieties.

Prof. C. A. Zavitz, of the Ontario Agricultural College, writes as follows regarding Burt and Early Ripe oats:[5]

> We obtained the Early Ripe variety from A. W. Livingston, seedsman, of Columbus, Ohio, in 1899, and the Burt from Dr. E. M. Freeman, of the U. S. Department of Agriculture, in 1906.
>
> We do not consider these valuable varieties, from an agricultural standpoint. In regard to rust, the Burt had 8 percent and the Early Ripe 6 percent, under similar conditions. There was only one variety, viz., Yellow Kherson, which has had less rust than the Early Ripe in the average experiment for 5 years.

The Livingston Seed Company of Columbus, Ohio, writes as follows, regarding Burt and Early Ripe oats:[6]

> We discontinued the handling of Early Ripe oats a number of years ago, and have none in stock at present, nor do we know of any in this section of the country.

[4] In March, 1901, the United States Department of Agriculture received a variety under the name "Sixty-Day" from Mr. C. I. Mrozinski, of Proskurov, in the Podolia government of Russia.

[5] Letter to the writer dated April 26, 1916.

[6] Letter to the writer dated May 2, 1916.

We secured our stock when we commenced growing it of A. L. Reese, Shelbyville, Ky. Where Mr. Reese secured the oats we do not know.

It is our judgment that the oats that we listed at that time under the name of Early Ripe is identically the same as the oats which came out some years later under the name of Burt. However, we are not sure that they are exactly the same. Mr. J. H. Burrow, of Linnville, Tenn., in a circular letter, claims that this oat originated in Green County in south Alabama, in 1878, by a man by the name of Burt. Further than this we are unable to trace it. Whether Mr. Burrow is still living or not, we do not know, as we have not heard from him direct for a number of years.

If there is any difference between Early Ripe and Burt oats, we were unable to distinguish what the difference was when growing them. We discarded them because there was not enough demand for them to justify continuing to keep them up from year to year.

Mr. C. W. Warburton, of the U. S. Department of Agriculture, writes as follows regarding the Burt oat:[7]

I do not know very much about the origin of the Burt oat, though it apparently was first grown in Tennessee. This variety is most extensively grown in Tennessee and adjoining states, from spring seeding. It also has done very well in our tests at Amarillo, Tex., and at Akron, Colo., and in varietal trials at the Nebraska station. It is strictly a southern oat, being of little value anywhere in the North. It is grown most extensively by farmers in Tennessee.

In the northern half of the Southern States it is apparently one of the best varieties for spring sowing. It is not adapted to fall sowing, as it is not winter hardy.

Prof. C. A. Mooers, of the Tennessee Agricultural Experiment Station, has written to Mr. Warburton as follows regarding the Burt:[8]

I am sorry to say that I can not give you with any certainty the origin of our Burt oats. As you say, it has been grown in the State for a good many years. Some fifteen years ago I met an elderly gentleman, the editor of a local paper in middle Tennessee, who told me he knew the history of the Burt oats; that it originated in Alabama, where a farmer noticed in his field of spring oats, presumably Red Rustproof, a plant which was ripe, while all the others around it were still green. He saved the seed, which was the beginning of the Burt oat. As I remember it, this was said to have occurred in the 60's or 70's.

Experimental Methods.

The methods of sowing, inoculating, and note taking were the same as those described in detail in another paper (15), and hence a brief discussion of them will suffice here.

The crown or leaf rust, *Puccinia lolii avenae* McAlpine, and the stem rust of oats, *Puccinia graminis avenae* Erikss. and Henn., were used in these experiments. Urediniospore cultures of both rusts were

[7] Letter to the writer dated May 3, 1916.

[8] Letter dated April 11, 1916.

obtained from the Minnesota Agricultural Experiment Station and were increased on seedling plants of a susceptible oat variety, for use in inoculating the parent varieties and the hybrids.

For the inoculations made on seedling plants, the seed was sown in 4-inch pots, at the rate of 15 seeds per pot. The seedlings were later thinned to 8 or 10 per pot, the usual number inoculated. Sowings of the parent varieties and of the F_2 generation hybrid seed were made each week in series of about 10 or 12 pots. Thus, during the winter, there were always some sowings just coming up, other series ready for inoculation, and still others on which the uredinia had appeared.

For the inoculations made on plants at time of heading, sowings were made during November in 5-inch pots. About 6 seeds per pot were sown, and the plants were later thinned to 2 or 3, which was the number usually inoculated and allowed to mature.

The seedlings were inoculated when in the second leaf, and were then about 3 to 5 inches in height. All inoculations were made on the first seedling leaf, by scraping urediniospores from a leaf bearing mature uredinia, and applying them to the moistened leaf surface with a flattened steel needle. One pot of seedlings of Sixty-Day was inoculated with each series of hybrids, to serve as a control culture.

Inoculations on the plants at time of heading were made in a similar manner, using crown rust on the upper leaf blades and stem rust on the upper sheaths and the peduncles.

Notes were taken in from 6 to 10 days on the appearance of flecks and uredinia, and records were kept of the number of leaves inoculated, the number on which flecks or uredinia appeared, and of any other points necessary in determining the classification of the plants as resistant, intermediate, or susceptible.

A plant was recorded as resistant when few or no normal uredinia ruptured the epidermis and where unmistakable signs of resistance were present. If the uredinia were numerous, large, and normal in appearance, and no very marked signs of resistance were present, the plant was included in the susceptible class. If there was a limited number of uredinia nearly normal in appearance, but accompanied by flecks, and if there were other indications of semi-resistance, the plant was classified as intermediate.

A great majority of the inoculations were made on seedlings, for the reason that greenhouse space for growing the plants to maturity was limited, as was also the quantity of hybrid seed available. The amount of space available in the special moist chamber used for the older plants had also to be considered.

No records were available of the behavior toward rust of the two strains of Burt and Sixty-Day used in making the cross, when grown under field conditions at Ithaca. Neither is it known whether the F_1 generation plants were resistant or susceptible. The plants of the F_2 generation inoculated in the seedling stage could not be grown to maturity, and there are no results therefore beyond the F_2 generation. The results to be described, then, include only those with pure-line material of the Burt and Sixty-Day parents and of the hybrid plants of the F_2 generation. These belonged to five distinct families, or progenies of F_1 generation plants.

Results of Experiments.

STEM-RUST INOCULATIONS ON SEEDLING PLANTS.

The experiments with stem rust were not as extensive as those with crown rust, for the reason that neither the Sixty-Day, the Burt, nor any of the hybrids showed any resistance to stem rust. Only enough seedlings were inoculated to definitely prove this fact. There were 32 plants of Sixty-Day inoculated and all were found to be very susceptible. Fifty-two plants of Burt were used and gave similar results (see Plate 1, *C*). Eighty-five F_2 generation hybrids were inoculated as seedlings and all showed complete susceptibility to stem rust.

CROWN-RUST INOCULATIONS ON SEEDLING PLANTS.

The experiments with crown rust gave quite different results, for altho one of the parent varieties, Sixty-Day, also proved to be completely susceptible to this rust (see Plate 1, *B* and *F*), the other, Burt, gave definite evidence of being resistant. This was not true of all the seedling plants, for some were just as susceptible as those of Sixty-Day. Some of the hybrid plants also were extremely resistant, while others were entirely susceptible. The results of inoculations of crown rust on seedling plants of Burt oat are given in Table 1.

TABLE 1.—*Inoculations of crown rust on seedlings of Burt oat.*

	Number.	Percent.
Seedlings classified as resistant	48	21.5
Seedlings classified as intermediate	152	68.2
Seedlings classified as susceptible	23	10.3
Total	223	100.0

These figures show that, altho the variety may be said to possess a rather high degree of resistance, there are many individual plants which are only semi-resistant and some which are quite susceptible. This fact also is shown very clearly in Plate 1.

The fact that all of the Burt plants did not prove resistant shows that the strain used was not homozygous for the character, resistance to crown rust. This does not contradict the statement that the parental varieties were pure lines, for it is well known that a plant or line may be homozygous for some characters and heterozygous for others. This strain had, in fact, been found to be pure with regard to the usually observed agronomic characters.

No satisfactory explanation of the occurrence of the semi-resistant and susceptible plants can be given, without knowing the hereditary behavior of the character in other generations. It does not seem likely that factors of environment or of the metabolism of the host plant can be given much consideration, for there often were marked differences in the degree of resistance manifested by plants grown in the same pot and inoculated at the same time from the same lot of urediniospores. An effort was made always to keep all external factors as uniform as possible. The different degrees of resistance can hardly be considered as mere fluctuations, but should rather be attributed to differences in genetic constitution of the plants.

Whatever may be the underlying cause of this sharp variation in resistance of the Burt plants, true resistance certainly is present in many of them and the results with the hybrids indicate that the particular plants used in making the cross carried the factor or factors for resistance, for the resistant character appears unmistakably among plants of the F_2 generation. The most resistant segregates appear to be fully as resistant as any of the resistant individuals among the Burt parent. The lack of uniformity in the resistance of plants of the Burt strain, however, makes it more difficult to interpret the results obtained in the F_2 generation, for the genotypic constitution of this parent as regards rust resistance is not known.

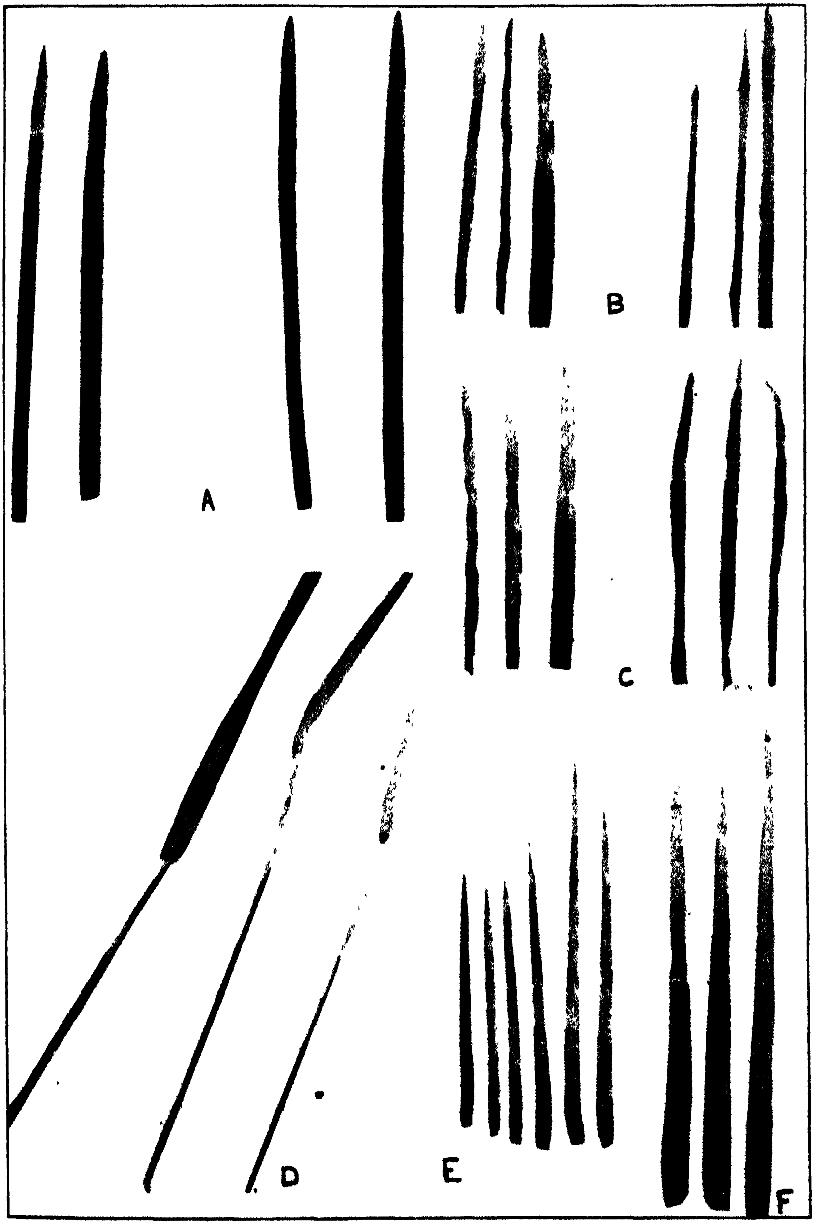
The inoculations of crown rust on seedlings of the F_2 generation included 468 individuals. The results are shown in Table 2.

TABLE 2.—*Inoculations of crown rust on seedling of Burt × Sixty-Day hybrids.*

Family.	No. of plants inoculated.	Resistant.		Intermediate.		Susceptible.	
		Number.	Percent.	Number.	Percent.	Number.	Percent.
2501 A-J. .	172	50	29.1	24	13.9	98	57.0
2501 A-P .	114	23	20.1	17	14.9	74	65.0
2501 A-R .	51	1	1.9	7	13.7	43	84.4
2501 A-H .	64	4	6.2	3	4.6	57	89.2
2501 A-N .	67	3	4.4	10	14.9	54	80.7
Totals . .	468	81	17.3	61	13.0	326	69.7

The basis of classification was the same as that used in the experiments with Burt, and has been described. It should be said that the word intermediate is not used in its strict genetic sense, for it is not known whether or not these semi-resistant plants will produce progenies resembling those of true hybrid intermediates (heterozygotes). The word refers rather to the relative quantity of rust, tho number of uredinia alone was never used as a determining factor in classifying a plant. Plants put in the intermediate class usually showed some signs of resistance, such as unusually small uredinia, presence of flecks, etc., but had too many nearly normal uredinia to be classed as resistant. The classification is an arbitrary one and is based only on phenotypic appearance, tho it is probable that the plants in the resistant group belong to a common genotype.

True segregation occurred and was plainly evident in the hybrid plants. This is indicated by the numerical results and is clearly shown in Plate 2. On the very resistant plants almost no uredinia were able to rupture the epidermis, while flecks and larger areas of dead host tissue, so characteristic of resistant varieties, are plainly visible. On the susceptible plants there are normal uredinia, the surrounding leaf tissues are still green, and there are no indications of resistance. The segregation was just as sharp as that observed in crosses involving morphologic characters, while some of the hybrid groups showed what appeared to be almost a complete series of transition forms between the wholly susceptible and the very resistant extremes, as illustratd in Plate 2, *C*. Such a series often is obtained in the F_2 generation where size characters or other complex quantitative differences are involved. Altho all the plants were put into three groups or classes, it was clearly recognized that all of those in the intermediate class were not exactly alike phenotypically, nor is it to be assumed that they all belong to the same genotype. In fact, they probably represent a rather complete series, which closely approaches the susceptible group at one extreme and the resistant group at the other. It would be very difficult, if not impossible, to measure accurately and rank properly the individuals of such a series. There is no definite standard which can be used, as there is for size differences which can be measured and recorded in figures, or those where the results of chemical analyses may be used. It is probable that most of the individuals in the intermediate class would be described as resistant, if considered in direct comparison with those of a very susceptible variety. They did not, however, show the extreme resistance of some of the Burt plants.


A
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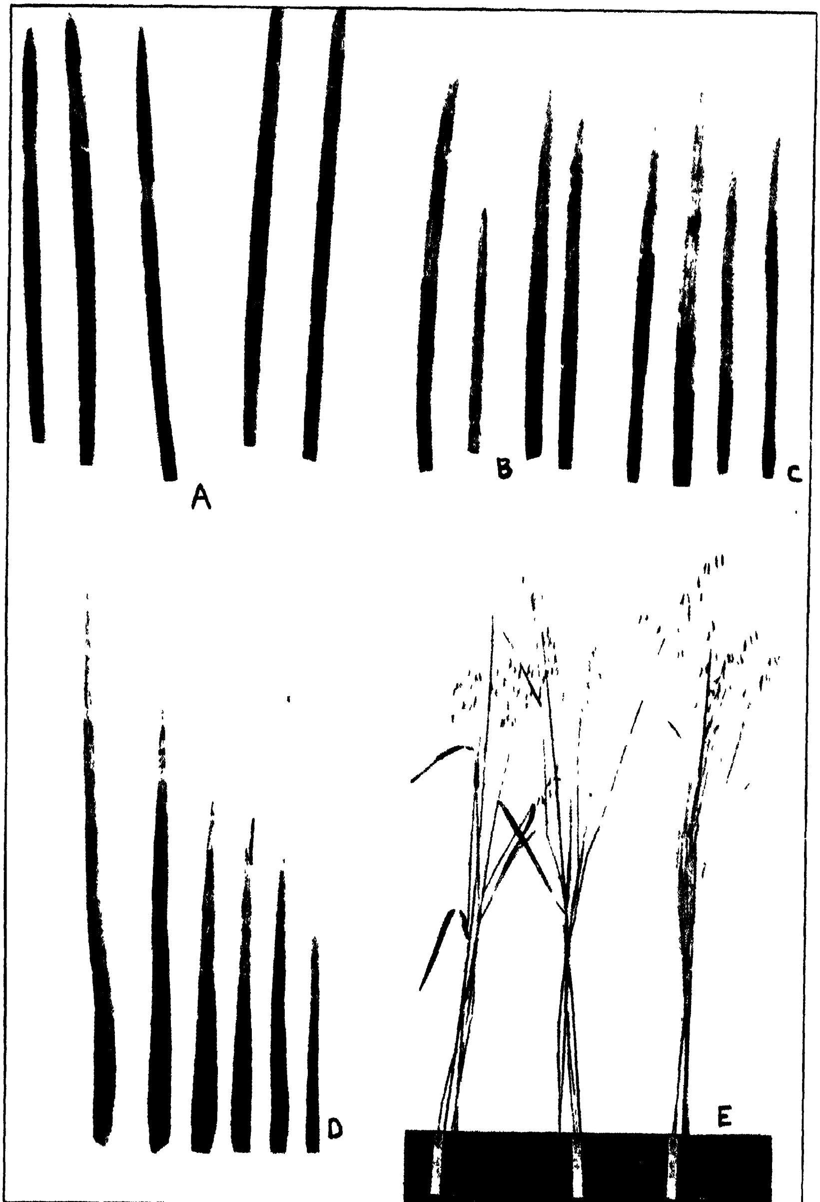
A
B
C
D
E

Whether the figures from each of the five hybrid families are considered separately or whether merely the totals are used, they show very clearly and positively that there were many more susceptible than resistant individuals. The total figures show that if only the two groups, resistant and susceptible, are considered, there were approximately four times as many susceptible as resistant individuals.

These results suggest that rust resistance is the recessive character and rust susceptibility the dominant one, and agree in this respect with Biffen's work with wheat, mentioned above.

It is evident from Table 2 that the percentage of resistant plants was considerably lower in the last three families than in the first two. These results may be explained on the assumption that the Burt parent plant was heterozygous as to rust resistance. The study of the Burt material itself strengthens this view and, if it is correct, then different F_2 generation families, i. e., progenies from distinct F_1 generation plants, would be expected to have different ratios of resistant and susceptible individuals.

INOCULATIONS ON PLANTS AT TIME OF HEADING.

Four culms of the Sixty-Day oat were inoculated with stem rust. Two were heavily rusted, the other two produced a few normal uredinia. Of the four upper leaf blades which were inoculated with crown rust, three were very heavily rusted, and the fourth had some normal uredinia. These upper leaf blades infected with crown rust are shown in Plate 1, *F*. These results on plants inoculated at time of heading confirm the fact established by the experiments with seedlings, that the Sixty-Day variety is susceptible to both stem rust and crown rust.

Six culms of the Burt oat were inoculated with stem rust. Heavy infections with large, confluent uredinia developed on three, while on the other three the uredinia were normal but fewer in number.

Six upper leaf blades were inoculated with crown rust and, altho some normal uredinia were produced on all the leaves, none had a large number of them. A more significant fact was the occurrence of numerous flecks, a condition characteristic of resistant plants. The very sharply contrasted types of infection resulting from crown-rust inoculation on leaves of the two parent varieties, Burt and Sixty-Day, are shown in Plate 1, *E* and *F*. The conclusions reached from the results of inoculations made at the time of heading on plants of the Burt parent are the same as those arrived at from the experiments with seedlings, i. e., that the Burt strain used is completely

susceptible to stem rust, but that at least some plants are resistant to crown rust.

Eight culms of the F_2 generation hybrid plants were inoculated with stem rust, and heavy infections resulted on all of them. Eight upper leaves were inoculated with crown rust. The infection on one was very heavy; on one fairly heavy; on four slight, with no normal uredinia; on one flecks only were evident; and on one there were no visible signs that infection had taken place. The upper leaf blades shown in Plate 2, *D*, were selected from the series just described, and offer good evidence of the segregation of resistant and susceptible plants in the F_2 generation.

The results from the limited number of hybrid plants which were inoculated at time of heading fully confirmed those obtained from seedlings, and show that the hybrid plants were all susceptible to stem rust, but that there were segregates which were resistant to crown rust and others which were susceptible.

Discussion of Results.

On the basis of this preliminary work, it is hardly possible to attempt the construction of a factorial hypothesis to fit the results. It is not desired, either, to put much emphasis on the ratios obtained, because of these facts: (1) The F_1 generation plants were not observed, and nothing is known of their resistance or susceptibility; (2) the number of F_2 generation plants observed was relatively small, and as these were not grown to maturity, the problem was not studied in the F_3 generation; (3) one of the parent varieties apparently was in a heterozygous condition for the character, rust resistance.

The fact that in the F_2 generation more than three times as many susceptible as resistant segregates appeared indicates that susceptibility to crown rust is partially dominant and that resistance to the same rust is recessive. This question of dominance could be definitely answered only by knowing the behavior of the F_1 generation plants, when grown under conditions favorable for rust. The question of dominance and recessiveness is not one of major importance and little emphasis is placed on it by more recent investigators of genetic problems. The facts of segregation and recombination of characters according to Mendelian laws are of much greater significance. The question of linkage also is now recognized as being of great importance, because of its possible interference in the production of new and desired factor combinations.

There can be no doubt that segregation did occur with respect to

the character, resistance to crown rust. Little is known, however, as to the particular recombinations which took place, that is, of the relation of rust resistance to other inherited characters. Neither is the real nature of the plants classified as intermediates known. Only by means of further breeding experiments can it be shown whether or not they are true hybrid intermediates, and what are their genotypic or factorial constitutions.

Until the basis of rust resistance is much better understood than at present, it may not be possible to discover the exact manner in which the character is inherited. The most important fact brought out in the course of these experiments is that resistance to crown rust is a heritable character and that it appears in a certain number of the F_2 generation plants. Other plants of the same generation show varying degrees of resistance, ranging all the way to complete susceptibility.

It is not well to go far into generalizations, but it may be said that as these results have been obtained in the cross, Burt × Sixty-Day, it is likely that similar ones would follow in other crosses between varieties of the *Avena sterilis* group which are resistant to crown rust and varieties of the *Avena sativa* group which are susceptible.

Contrasted characters such as resistance and susceptibility almost certainly involve extremely complex physiological processes, perhaps to an extent modified by outside factors but primarily determined by heredity. The F_2 generation results, especially the difficulty of classification, indicating the presence of a rather complete series of forms, do not favor the view that the character is a simple one, determined by a single factor difference. It seems more likely, as Nilsson-Ehle has found with regard to yellow rust (*Puccinia glumarum*) in wheat, that the observed gradations between resistant and susceptible plants are due to several determiners recombined by crossing. In other words, the character of rust resistance is probably dependent on multiple factors. At least, that hypothesis will account for the results so far obtained, altho the number of these factors, their basis, and their exact behavior in heredity are still to be determined.

Summary.

1. Pedigree lines of two oat varieties, Burt and Sixty-Day, together with a large number of F_2 generation hybrids between these varieties, were studied in relation to their rust resistance. Most of the inoculations were made on seedlings, but enough were made on plants at time of heading to show that the results were similar.

2. The rusts used were the crown rust of oats, *Puccinia lolii avenae* McAlpine, and the stem rust of oats, *Puccinia graminis avenae* Erikss. and Henn.

3. Burt and Sixty-Day and all the hybrids of these two varieties so far tested were found to be entirely susceptible to stem rust.

4. All plants of Sixty-Day also were uniformly susceptible to crown rust. Of 223 inoculated plants of Burt, 48 were classified as resistant, 152 as intermediate, and 23 as susceptible.

5. Each of the five hybrid families contained, in the F_2 generation, some plants showing a high degree of resistance to crown rust and others which were as susceptible as plants of the Sixty-Day parent. In other words, there was definite segregation. There was, however, a rather large number of plants which were classified as intermediate and which showed varying degrees of resistance.

6. The numerical results of inoculations made in the F_2 hybrids were as follows:

	Number.	Percent.
Seedlings classified as resistant	81	17.3
Seedlings classified as intermediate	61	13.0
Seedlings classified as susceptible	326	69.7
Total	468	100.0

7. The fact that there were so many more susceptible than resistant plants indicates that susceptibility to crown rust in this cross is partially dominant, while resistance is recessive.

8. These contrasted characters are not thought to be due to environmental conditions or to differences in the metabolism of the host plants, but to definite genetic factors. Nonhereditary factors may of course influence or modify their expression.

9. Rust resistance and susceptibility hardly can be considered as simple characters or as being determined by a single factor difference.

10. The F_2 generation results, particularly the rather complete series of forms showing varying degrees of resistance and necessarily classified as intermediates, favor the view that several factors are involved, i. e., the multiple factor hypothesis.

11. No attempt has been made to construct a definite factorial hypothesis to explain the results obtained.

12. This preliminary work has proved the possibility of transferring the character of resistance to crown rust from the Burt variety to plants of the F_2 generation of a Burt $\times$ Sixty-Day cross.

13. This suggests further use of the method of hybridization in the effort to produce rust-resistant varieties of oats for culture in the several oat districts of the United States.

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Legends for Plates.

Plate 1. *A.* **Seedling leaves of Burt oat inoculated with crown rust, showing resistant (left) and susceptible (right) strains.**

B. **Seedling leaves of Burt oat (left) resistant to crown rust, and of Sixty-Day oat (right) susceptible.**

C. Seedling leaves of Burt oat inoculated with crown rust (left), showing sharp resistance, and inoculated with stem rust (right), showing susceptibility.

D. Upper leaf blades and sheaths of the same plants as in Plate 2, *E,* showing susceptibility of all three to stem rust and susceptibility of Sixty-Day to crown rust, contrasted with sharp resistance to crown rust of the hybrid and Burt.

E. Upper leaf blades of resistant Burt oat, from plants inoculated with crown rust at time of heading, showing flecks, indicative of resistance, but almost no uredinia.

F. Upper leaf blades of susceptible Sixty-Day oat, from plants inoculated with crown rust at time of heading, showing normal uredinia.

PLATE 2. *A.* Seedling leaves of F_2 hybrids (Burt × Sixty-Day) inoculated with crown rust, showing resistant (left) and susceptible (right) segregates.

B. Same as *A*, but of another F_2 family.

C. Same as *A,* but of another F_2 family.

D. Upper leaf blades of F_2 hybrid plants (Burst × Sixty-Day) inoculated with crown rust at time of heading. One leaf (left) has numerous uredinia, others have very few uredinia but show sharp flecks, indicating resistance.

E. Plants of Sixty-Day, F_2 hybrid, and Burt oats (left to right), inoculated at time of heading, showing crown rust on upper leaf blades and stem rust on upper leaf sheaths.

FORMALDEHYDE TREATMENT OF SEED CORN.[1]

FREDERICK D. RICHEY.

In an effort to prevent the growth of fungi on corn seedlings grown in water culture, the seed was first treated with formaldehyde solutions of different strengths and for different periods. This seed was then tested for germination and notes made on the early growth of the seedlings both in water culture and, for purposes of comparison, in sand. The results obtained from these tests form the basis for the present paper.

METHODS AND MATERIALS.

The samples used consisted of 25 kernels, taken 1 kernel from each of 25 ears, of U. S. Selection 201 grown at Armorel, Ark., in 1918. Each treatment was given to 4 samples. The strength of the solutions is given as cubic centimeters of "Liquor Formaldehyde, U. S. P." (containing about 39 percent H·CHO) per liter of solution, ordinary tap water which had been boiled for 30 minutes and then cooled being used for dilution.

The samples were soaked in the solutions for 30 minutes or for 2 hours, as indicated, after which the surplus was drained off and the containers closed for a period of fuming or penetration. The time of soaking plus the time of fuming gives the total period of treatment.

GERMINATION EXPERIMENTS.

Two sets of samples were tested for germination in water germinators designed by Mr. C. H. Kyle, in which the kernels were supported on trays of woven wire cloth so that they could be immersed in water to the desired depth. For purposes of comparison, a set was also grown in sand; while to ascertain the residual effect, one set of samples was dried to its original weight, held for 16 days, and then grown in sand. One untreated sample and three which had been soaked in boiled tap water were germinated in each case as controls. The experiments were conducted in a greenhouse in which the temperature usually approximated 80° F. and varied from 70° to 87° F., which may be taken for the germination temperatures of the samples in water germinators. The temperature 1.5 inches below the surface

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication October 30, 1919.

of the sand (the depth at which the plantings were made) approximated 70° F. thruout the experiment.

Daily counts were made of the radicles and plumules appearing on the kernels in the water germinators, of the seedlings infected with fungi, and of those in which infection was severe. Germination in sand was based on the number of plants emerging. After germination was apparently completed, the plants were measured and the rate of growth after emergence was calculated.

RESULTS IN WATER CULTURE.

Table 1 shows the percentage germination of the samples based on counts of radicles and of plumules, and the rapidity of germination and growth based on the emergence and measurements of plumules.

TABLE 1.—*Germination and growth of corn in water culture as influenced by treatment with formaldehyde.*

Sample No.	Treatment.			Seed producing radicles			Seed producing plumules.			Average rapidity of—	
	Formaldehyde per liter.	Time soaked.	Total period.	Box 1.	Box 2	Average.	Box 1.	Box 2.	Average	Germination.	Growth per day.
	c.c.	*Min.*	*Hours.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Per-cent.*	*Days.*	*Inches.*
13	No treatment			100	96	98	72	64	68	3.44	1.129
22	0	120	3.5	100	100	100	76	84	80	3.11	1.080
5	0	120	8.5	100	100	100	84	80	82	3.05	1.268
14	0	120	26.5	100	100	100	60	72	66	2.61	1.041
2	5	30	3.5	100	100	100	100	96	98	3.59	1.432
23	5	30	8.5	100	96	98	100	96	98	3.02	1.329
19	5	30	26.5	100	96	98	100	88	94	3.43	1.374
3	5	120	3.5	100	96	98	96	96	96	3.44	1.352
10	5	120	8.5	100	100	100	96	80	88	3.30	1.226
6	5	120	26.5	100	100	100	96	100	98	2.98	1.212
4	15	30	3.5	96	100	98	96	100	98	3.21	1.229
12	15	30	8.5	100	100	100	92	96	94	3.69	1.333
8	15	30	26.5	100	96	98	96	92	94	3.48	1.115
24	15	120	3.5	96	100	98	96	100	98	3.30	1.230
20	15	120	8.5	100	100	100	92	100	96	3.38	1.156
15	15	120	26.5	96	96	96	80	80	80	3.38	1.103
25	25	30	3.5	100	100	100	96	100	98	3.56	1.365
21	25	30	8.5	92	92	92	80	84	82	3.42	1.151
16	25	30	26.5	88	72	80	80	56	68	3.71	0.852
11	25	120	3.5	100	96	98	80	84	82	3.66	1.120
7	25	120	8.5	84	88	86	72	68	70	3.83	0.908
17	25	120	26.5	76	36	56	56	24	40	3.62	0.765

The samples treated with the 25 c.c. solution for 8.5 and 26.5 hours evidently were injured, as shown by the low percentage of radicles and still lower percentage of plumules. Samples 15 and 11, tho not showing any injury when measured by the percentage of radicles, were unable to develop their full number of plumules. The quantitative germination of the other treated samples does not seem to have been affected, the low germination of sample 10 in box 2 evidently being accidental.

Altho the untreated and water-treated samples showed practically perfect germination, based on radicle counts, they were so severely infected by fungi that they were unable to put forth plumules, and show poor germination based on plumule counts.

TABLE 2.—*Influence of formaldehyde treatment on fungous infection of seedlings in water culture.*

Sample No.	Treatment. Formaldehyde per liter.	Time soaked.	Total period.	Infected seedlings at stated periods from beginning of test. 3 days.	4 days.	5 days.	6 days. Total.	6 days. Severe.
	c.c.	*Minutes.*	*Hours.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
13	No treatment			47	44	76	91	59
22	0	120	3.5	30	49	95	95	85
5	0	120	8.5	34	53	68	80	51
14	0	120	26.5	67	76	88	97	73
2	5	30	3.5	5	11	13	27	4
23	5	30	8.5	0	4	25	47	16
19	5	30	26.5	0	4	21	45	21
3	5	120	3.5	0	0	10	19	6
10	5	120	8.5	0	0	9	23	2
6	5	120	26.5	0	0	16	37	2
4	15	30	3.5	0	2	10	31	10
12	15	30	8.5	0	0	7	43	6
8	15	30	26.5	0	0	11	45	13
24	15	120	3.5	0	0	10	41	12
20	15	120	8.5	0	0	9	44	15
15	15	120	26.5	0	3	11	63	23
25	25	30	3.5	0	0	4	27	10
21	25	30	8.5	0	0	10	37	5
16	25	30	26.5	0	0	3	47	6
11	25	120	3.5	0	3	8	49	5
7	25	120	8.5	0	0	11	29	3
17	25	120	26.5	0	0	0	70	30

The rapidity of germination and growth, while not materially affected by treatment with the 5 c.c. or 15 c.c. solutions, was checked

by the use of the 25 c.c. solution. The seedlings from the samples treated with the 5 c.c. solution were the most uniform, having an average coefficient of variability of 32.0 percent against 47.9 percent for the untreated and water-treated samples and 41.8 and 49.8 percent for those treated with the 15 and 25 c.c. solutions, respectively.

Fungous infection was apparent on the sixth day on 46 of the 53 seeds which failed to germinate, and on 98 of the 112 which developed radicles but no plumules, while in both these classes the few uninfected kernels were distributed among the samples without apparent relation to the treatment. The infection on the seedlings, which was quite severe in the case of the untreated samples, was markedly checked by all the treatments, being held practically to nothing until the fifth day, particularly in the case of samples 3, 10, and 6 (Table 2).

RESULTS OF GERMINATION IN SAND.

TABLE 3.—*Germination and early growth of corn in sand as influenced by treatment with formaldehyde.*

Sample No.	Treatment.			Tested immediately after treatment.			Tested 16 days after treatment.		
	Formaldehyde per liter.	Time soaked.	Total period.	Germination. Percent.	Germination. Rapidity.	Growth per day.	Germination. Percent.	Germination. Rapidity.	Growth per day
	c.c.	*Minutes.*	*Hours.*		*Days.*	*Inches.*		*Days.*	*Inches.*
13	No treatment			96	5.58	1.387	100	4.33	1.031
22	0	120	3.5	96	5.92	1.338	96	4.44	0.883
5	0	120	8.5	96	4.96	1.397	100	4.22	0.926
14	0	120	26.5	100	4.96	1.429	100	4.25	1.013
2	5	30	3.5	100	5.38	1.437	100	4.43	0.858
23	5	30	8.5	100	5.71	1.203	100	4.56	0.807
19	5	30	26.5	96	5.58	1.217	100	4.67	0.777
3	5	120	3.5	96	5.54	1.345	100	4.60	0.869
10	5	120	8.5	100	5.46	1.251	100	4.44	0.866
6	5	120	26.5	96	5.33	1.259	96	4.39	0.852
4	15	30	3.5	100	5.42	1.170	88	5.00	0.705
12	15	30	8.5	96	5.67	1.088	88	5.51	0.696
8	15	30	26.5	96	5.75	1.068	76	5.54	0.617
24	15	12	3.5	100	6.00	1.150	40	5.55	0.514
20	15	120	8.5	96	5.79	1.040	60	5.92	0.526
15	15	120	26.5	92	5.79	1.043	72	5.68	0.596
25	25	30	3.5	100	6.08	1.112	40	5.75	0.634
21	25	30	8.5	100	5.96	1.030	24	6.21	0.486
16	25	30	26.5	60	6.29	0.863	16	7.25	0.400
11	25	120	3.5	96	6.00	1.105	8	6.63	0.572
7	25	120	8.5	92	6.29	1.032	8	5.25	0.435
17	25	120	26.5	40	7.04	0.878	0	....	....

Table 3 gives the percentage of germination and the rapidity of germination and growth in sand, both as tested immediately after treatment and 16 days after treatment. The samples tested immediately after treatment gave practically perfect germination except 16 and 17, in which there was evidence of injury. Of the samples held for later testing, the untreated sample, those treated with water only, and those treated with the 5 c.c. per liter solution gave perfect germination, while the germination of the samples treated with the 15 c.c. and 25 c.c. solutions was reduced, the longer and stronger treatments resulting in the lowest percentages of germination.

The rapidity of germination in either sand test was not materially affected by treatment with the 5 c.c. solution, while it was somewhat checked by the use of the 15 c.c. and 25 c.c solutions. The rapidity of growth was lessened by all treatments, though not materially so by treatment with the 5 c.c. solution.

Conclusions.

Treatment of seed corn with solutions of 5, 15, and 25 c.c. of formaldehyde per liter materially reduced the development of fungi on the plants grown in water culture.

The vitality of the seed, as evidenced by the development of the seedlings in either water culture or sand, was not affected by treatment with the solution of 5 c.c. of formaldehyde per liter. Treatment with the solution of 15 c.c. of formaldehyde per liter did not materially affect the seedlings grown in water culture, but nevertheless was injurious as evidenced by the germination and development in sand. Treatment with 25 c.c. per liter was markedly deleterious.

The germination and growth of samples 3, 10, and 6 was not affected by the treatments given, and the seedlings were remarkably free from fungi. Soaking seed corn for 2 hours in a solution of 5 c.c. Liquor Formaldehyde in 995 c.c. of water, followed by a fuming period of from 2 to 24 hours, can therefore be recommended as checking fungous development, without interfering with the normal development of corn seedlings in water culture.[2]

[2] Investigation of disease prevention in corn culture was no part of the purpose of the foregoing experiments, nor were they made with any specific fungus in mind. Microscopic examination of eight of the severely infected seedlings from the water culture, however, showed the typical crescent shaped macroconidia of Fusarium to be present in every case. It is also known that the field in which the seed used in these tests was grown in 1918 was rather heavily infested with Fusarium. With these facts in mind, the marked reduction of fungous infection on the plants from the seed treated with formaldehyde indicates the possibility of reducing the amount of Fusarium in cultivated fields, insofar as this may be due to spores carried externally on the seed.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership of the Society reported in the November, 1919, issue was 550. Since that time, 11 new members have been added, making a total membership of 561. The names and addresses of the new members, with such changes of address as have been reported, follow.

NEW MEMBERS.

CARLSON, F. A., Dept. Soil Technology, Cornell University.
COFFMAN, F. A., Akron Experiment Farm, Akron, Colo.
GORDON, F. E., Hardin, Mont.
GRAVES, CHAS L., State College, Brookings, S. Dak.
HART, J. C., Blacksburg, Va.
HELMICK, BEN C., 13 Pond St., Orono, Maine.
HENDRIX, W. R., Agronomy Dept., La. State Univ., Baton Rouge, La.
McFADDEN, E. S, Highmore Substation Highmore, S. Dak.
MACHLIS, KOS. A., Station A, Brookings, S. Dak.
SWANSON, A. F., Experiment Station Hays, Kans.
WORTHEN, E. L., Dept. Soil Technology, Cornell Univ., Ithaca.

CHANGES OF ADDRESS.

TROUT, C. E., Oakhurst Farms, Jacksonville, Fla.
VAN NUIS, C. S., 134 Livingston Ave., New Brunswick, N. J.
WERMELSKIRCHEN, LOUIS, Glenwood, Iowa.
WILKINS, F. S., Iowa State College, Ames, Iowa.
WOLFE, T. K., Box 413, Ithaca, N. Y.

NOTES AND NEWS.

P. V. Cardon, who has been superintendent of the Judith Basin Experiment Farm, Moccasin, Mont., for the past two years, has been elected professor of agronomy in the Montana State College and agronomist of the station, succeeding Alfred Atkinson, now president of the Montana college. Mr. Cardon will begin his new duties on March 1.

J. Stanley Cobb has been appointed instructor in agronomy at the Pennsylvania State College, and J. Stanley Owens has been made instructor in agronomy extension in the same institution.

Carl G. Degen has been appointed assistant in agronomy at the Pennsylvania station.

W. R. Dodson, dean of the college of agriculture of Louisiana State University and director of the Louisiana station for the past twenty-five years, has resigned, effective January 1.

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FEDERAL SEED GRAIN LOANS.[1]

C. W. WARBURTON.

For the first time in the history of the United States, direct loans have been made by the Federal Government to farmers to enable them to meet conditions of financial stress caused by crop failures. On several previous occasians relief has been provided by Congress for those whose crops had been destroyed by floods or other calamity, but this relief has been in the form of the free distribution of seed without expectation of return. For the past three years the Federal Land Banks have made loans on farms, but their funds are derived from the sale of farm-mortgage bonds and the loans are secured by mortgages on improved farm land. In the present instance, Federal funds were loaned to farmers who could give no security other than a mortgage on the crop which they expected to produce. Because these loans are without precedent in our history, it seems worth while to record the conditions under which they were made and to discuss some of their agronomic phases.

The demand for Federal aid to enable farmers to maintain or to increase their acreage in food crops came first from Kansas, where a very large part of the wheat sown in 1916 and 1917 had been destroyed by drouth and winterkilling. A delegation from that State came to Washington in June, 1918, and presented figures to the Congressional committees on agriculture which indicated that, if Federal aid was not given, a greatly reduced acreage of wheat would be sown

[1] Contribution from the Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Read by title at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 10, 1919, in the absence of the author.

in western Kansas in the fall of 1918. According to the estimates presented, it was probable that not more than 1,300,000 acres of wheat could be sown in the western half of the State without Federal aid, whereas double this acreage had been sown the previous year and would be sown in 1918 if aid was given. Similar reports came from western Oklahoma, and a little later requests for Government aid came from Montana, where drouth in 1917 and 1918 had greatly reduced the yields of wheat and other crops.

Several bills were introduced in Congress during the summer of 1918 appropriating various sums of money for extending aid to farmers in the drouth-stricken areas, but is soon became apparent that action on these could not be obtained quickly enough to help farmers put in their fall-sown crops. Late in June, 1918, Congress had authorized an appropriation of $100,000,000 as a war emergency fund for "the national security and defense," which could be used by the President for any purpose that in his opinion would help to win the war. On July 26, 1918, on recommendation of the Secretary of the Treasury and the Secretary of Agriculture, the President set aside $5,000,000 of this fund for farmers' seed grain loans. The conditions of the loans were set forth in Joint Circular No. 1 of the Treasury Department and the Department of Agriculture, the President having designated these two departments to administer the fund. The Federal Land Banks of the respective districts in which the drouth-stricken areas were located were named as financial agents of the United States to make and collect the loans.

For purposes of administration by the Department of Agriculture, the drouth-stricken areas were divided into two districts, the northern one including western North Dakota and northern Montana, and the southern one including western Kansas, western Oklahoma, northwestern Texas, and northeastern New Mexico. Mr. G. I. Christie, then Assistant to the Secretary, was designated to supervise the work in the northern district with headquarters at Great Falls, Mont., and Mr. L. M. Estabrook, Chief of the Bureau of Crop Estimates, that in the southern district, with headquarters at Wichita, Kans. Mr. H. N. Vinall and the writer assisted in the supervision of the work in the southern and northern districts, respectively. During August, several preliminary meetings were held in each district at which the conditions of the loans were explained by representatives of the Federal Land Banks and the Department of Agriculture, and plans were made for furthering the work. These meetings were attended by officials of the State extension departments, Farm Bureau presidents, county

agents, and other interested persons. While considerable dissatisfaction with the terms of the loan was expressed by some of those attending these meetings, the general opinion was that the plan should be given a thoro trial and that the best possible use should be made of the funds.

The agronomic features of the loan were under the general supervision of the Department officials previously mentioned, assisted by the extension divisions of the various States, including the county agents in the affected counties. Fortunately, county agents were located in a large portion of these counties, and in many there were farm bureaus, so that the organization was ready at hand. The local banks were designated by the Federal Land Banks as agents to receive applications for loans, and on the completion of certain preliminaries, the proceeds of the loans were forwarded to the farmers thru these banks.

In Joint Circular No. 1, it was stated that:

> The primary object of farmers' seed grain loans is not to stimulate the planting of an increased acreage of grain in the drouth areas, or even necessarily to secure the planting of a normal acreage, but rather to assist in tiding the farmers over the period of stress, to enable them to remain on their farms to plant such an acreage as may be determined to be wise under all the conditions, with a view to increase the food supply of the Nation and to add to the national security and defense. It is distinctly not intended to be used to stimulate the planting of wheat or any other grain where such planting is not wise from an agricultural point of view and where other activities are safer.

Loans were made only in areas that had suffered two successive crop failures from drouth or winterkilling, and to farmers who had land in condition for sowing and who, by reason of crop failures, had exhausted their resources and were without commercial basis of credit. No loan was to be made to any farmer who had unencumbered real or personal property sufficient to secure a loan of $300. The maximum loan to an individual was $300, and the maximum amount loaned per acre was $3.00. Loans were made on fall wheat and rye, and were secured by mortgages on those crops. Applicants for loans agreed to use seed and methods approved by the Department of Agriculture. These conditions were agreed to by representatives of the Department, the State college of agriculture, and the extension division. They were the minimum which it was felt must be provided if the farmer was to do his part in attempting to produce a crop, rather than the ideal conditions. For example, the requirements for the sowing of fall wheat and rye in Montana were as follows:

1. *Plowing.*—The land on which the grain is sown must have been well plowed since August 1, 1917. The plowing must have been sufficiently well done so that there is no evidence that the native sod is re-establishing itself.

2. *Condition of Seed Bed.*—The land should be free from weeds and must be sufficiently free to allow the uniform covering of the seed to the proper depth. Land which was sown to a crop in the fall of 1917 or the spring of 1918 must be mellow enough to allow seeding to a depth of at least two inches.

3. *The Seed.*—The seed sown must be of good quality and practically free from weed seeds. The seed must be of the hard red winter type of such varieties as Turkey Red, Kharkov, Crimean, or Alberta Red and must have been treated for smut either with formaldehyde or bluestone solution. The seed of both wheat and rye must germinate at least 80 per cent.

4. *Date and Rate of Seeding.*—The wheat must be sown not later than October 15 and the rye not later than November 1, 1918. Not less than 35 pounds of seed must be sown to the acre.

The original tentative allotment of the $5,000,000 fund was $1,750,000 to Montana, $600,000 to North Dakota, $1,250,000 to Kansas, $850,000 to Oklahoma, $350,000 to Texas, and $200,000 kept as a reserve fund. Later, on representations from Washington State officials and farmers, $200,000 of the amount originally allotted to Montana was set aside for loans in that State. A small allotment was also made to New Mexico.

The farmer who wished to obtain a loan filled out an application blank at his local bank, on which he stated the acreage he wished to sow to fall wheat or rye, the location and number of acres owned by him, and the number and value of each class of livestock. He also showed the mortgages against his real and personal property and the acreages in crops in 1917 and 1918, with the yields produced. This was followed by a sworn statement that he was unable to sow the stated acreage without the loan for which he was making application. In addition, a certificate was required from his local banker to the effect that the farmer's statement of his financial condition was essentially correct, and that he did not have sufficient basis for credit to secure a loan of $300. This was followed by a certificate from the local Farm Bureau regarding the applicant's credit condition and his reputation as a farmer and citizen, and also showing whether or not he had the stated acreage in condition for sowing. When the application was thus complete, it was forwarded to the central office, where is was examined and, if satisfactory, approved by the designated representative of the Department of Agriculture. It was then turned over to an official of the Federal Land Bank, who issued a certificate of approval. This certificate stated that the application for the loan had been approved, and that the money would be advanced by the

Federal Land Bank when a certificate of planting was issued by the county agent and the farmer had signed a note, mortgage, and guaranty fund agreement.

As the only security given by the farmer was a crop mortgage, it was essential that there be no question regarding the legality of this document, and that it be a first lien. For this reason loans were made only to land owners and homesteaders, as renters could not give an unconditional mortgage on their crops. Further, officials of the Treasury Department ruled that a legal mortgage could not be given on the crop until it was actually in existence, and that therefore the mortgage should not be signed nor the funds delivered to the farmer until the crop was sown. This condition was the cause of considerable criticism and, in occasional instances, worked hardship on the borrower, but local banks very generally accepted the certificates of approval as security for temporary loans to enable the farmer to purchase seed and sow the crop. As soon as the seed was sown a planting certificate was signed by the county agent and delivered to the applicant or to his banker. The banker then prepared the note, mortgage, and guaranty fund agreement for the borrower's signature, and when this was obtained these papers and the planting certificate were forwarded to the Federal Land Bank. When these all were in proper form remittance was made promptly.

The note was an ordinary promissory note bearing 6 percent interest. Those in the southwestern district were due October 1, 1919, and those in the northern district on November 1, 1919. The mortgage was a crop mortgage covering a specific acreage of wheat or rye, or both, sufficient to secure the amount of the loan at the rate of $3.00 per acre. The guaranty fund agreement was an agreement by which the borrower obligated himself to pay certain additional sums to the Federal Land Bank if the average acre yield of the acreage mortgaged exceeded 7 bushels. This fund was to secure the Government against loss due to crop failures and consequent inability of borrowers to pay their notes. An average yield of less than 5 bushels per acre was considered a crop failure under the terms of this agreement. Payments into the fund were to be at the rate of 15 cents per acre for each bushel by which the average acre yield exceeded 6 bushels, with a maximum payment of 75 cents per acre. Thus, if the average yield was 7 bushels, the payment was 15 cents per acre; if 8 bushels, 30 cents; if 9 bushels, 45 cents; if 10 bushels, 60 cents; and if 11 bushels or over, 75 cents. Any portion of this fund which remained after the losses occasioned by crop failures and consequent nonpayment were

adjusted was to be returned to those who had made guaranty fund contributions, each to receive his pro rata share according to the amount of his contribution.

Naturally, the county agent and the officers of the Farm Bureau could not be expected to know all the applicants nor to be familiar with conditions on their farms. This was particularly true in some of the larger counties. For instance, Dawson County in eastern Montana measured 170 miles from east to west and 60 miles from north to south. This county was divided early in 1919, but the county agent has continued to look after seed grain loan matters over all his original territory. To aid county agents and Farm Bureau officials in getting first-hand information, the Farm Bureau community committeemen were used. Forms were prepared on which they reported regarding the conditions on the farm of each applicant and the recommendations of the Farm Bureau Committee on the borrower's application were based on this report. Later, the Community Committee reported on the seeding, and on this information the county agent issued planting certificates.

Abundant rains in the southwestern district and generally favorable conditions for sowing caused a heavy demand for seed grain loans in Kansas, Oklahoma, Texas, and New Mexico, and a total of 8,806 applications were approved, totaling $2,025,262. In the northern district the moisture was generally insufficient for the best growth of fall-sown crops and the demand was much less than was anticipated, only 1,837 loans amounting to $371,788 being approved. This was due to the fact that North Dakota farmers generally were able to finance the sowing of rye and that there was no need for financial aid in the better fall wheat sections of Montana. There was practically no demand for loans in Washington, the $300 maximum being regarded by farmers in that State as too small to be of benefit.

After it became evident that only a small portion of the amounts allotted to the northern States would be used for loans on fall wheat and rye, arrangements were made to use the remainder of the fund for financing spring wheat seeding. About October 1, 1918, announcement was made that funds allotted to North Dakota, Montana, and Washington and not used for loans on fall wheat and rye would be available for loans on spring wheat at the rate of $5.00 per acre. If a loan had been obtained on 100 acres of fall wheat or rye, no loan on spring wheat was made. If a loan had been made on less than 100 acres of fall wheat or rye, the applicant could obtain a loan on the difference between 100 and his fall-sown acreage. If no fall loan had

been obtained, the limit on spring wheat was $500. The amount of the fall loan was fixed at $3.00 per acre because this amount was more than sufficient to purchase seed, and the borrower who put in fall grain could very generally arrange to leave his farm after the seeding was completed and obtain work at good wages to support his family during the winter. On the other hand, the borrower who put in spring wheat would almost necessarily have to remain on the farm from seeding until harvest, so that the increase from $3.00 to $5.00 per acre was necessary to provide funds for subsistence. No loans on spring grain were made in the southwestern district.

The demand for loans in the State of Washington was again very small, while the North Dakota demand was well within the allotment. In Montana, however, the call for funds was even greater than had been anticipated, and it was necessary to transfer $600,000 from unallotted funds and funds allotted to other States and unused, in order to grant all deserving requests. The number of approved applications for loans on fall wheat and rye and spring wheat, with the amounts of the loans in each of the several States, are shown in Table 1.

TABLE 1.—*Number and amount of approved seed grain loans by States.*

State.	Winter wheat and rye		Spring wheat.	
	Number.	Amount.	Number.	Amount.
North Dakota	338	$ 65,994	1,356	$ 484,217
Montana	1,481	301,159	5,295	1,850,285
Washington	18	4,035	40	12,895
Kansas	3,531	943,147		
Oklahoma	3,852	773,271		
Texas	1,336	292,651		
New Mexico	87	16,193		
Total	10,643	$2,397,050	6,691	$2,347,397

The procedure in making loans on spring wheat was the same as for making loans on fall wheat and rye. The experience gained during the previous fall, however, made the handling of the applications much easier, and the prompt payments made by the Federal Land Banks when the completed papers reached them added greatly to the confidence placed in the project by local bankers. The taking of applications for loans on spring wheat was completed well before the seeding season, and in general the crop was sown under favorable conditions. It was everywhere conceded that never before had farmers in the dry-land section made as great an effort to produce crops as they did in the fall of 1918 and the spring of 1919.

While approximately 800,000 acres of fall wheat and rye and 470,000 acres of spring wheat were mortgaged to secure the loans in the various States, the actual acreage seeded from the proceeds of the loan was considerably greater. No restriction was placed on the use of the funds other than the sowing of an acreage sufficient to secure the loan. In many cases the entire amount of the loan was used in the purchase of seed, so that the acreage sown was considerably greater than was needed to meet the requirements. The placing of approximately $5,000,000 of Federal funds in the drouth-stricken areas added materially to the confidence of bankers and other business men and made it much easier for farmers who had some commercial basis of credit to obtain funds to finance their seeding. As a consequence, the area sown to wheat and rye for the 1919 crop was increased perhaps as much as 2,000,000 acres by the making of Federal seed grain loans.

The early spring rainfall in Montana was sufficient generally to enable farmers to put their land in good condition for seeding and to insure prompt germination. In the triangle from Great Falls to Havre and west to the Continental Divide, as well as in portions of Fergus County, the rainfall was insufficient for germination and early growth, while in some portions of eastern Montana and generally in North Dakota heavy rains during the latter part of April and early May delayed seeding. A hot, dry period over Montana and North Dakota began about May 15, with temperatures during the latter half of May running to nearly 100° F. June and July temperatures were also far below normal, while generally the rainfall was below normal. For instance, the average mean temperature in Montana during June exceeded the normal by 4.5°, while the average precipitation for the State was 0.66 inch, as compared with a normal of 2.80 inches. In North Dakota the mean temperature was 4.4° above normal, and the rainfall was about two-thirds of the normal.

As a result, the tillers on rye in western North Dakota and Montana and on fall wheat in Montana were generally killed and only the central stems produced heads. Even these were dwarfed in many sections and matured little or no grain. A considerable part of the rye crop was cut for hay. In some localities showers which fell about July 1 benefited the spring wheat crop, but the average yield of wheat in the sections of Montana where seed grain loans were made and in North Dakota west and south of the Missouri River probably did not exceed 2 bushels to the acre. North of the Missouri River in North Dakota the conditions generally were more favorable and fair yields were produced, altho even here the extreme heat cut the yields to half those which were in prospect shortly before harvest.

In the southwestern district conditions were very favorable during the fall of 1918 and the suceeding winter. The snowfall was heavy, and there was practically no winterkilling. In New Mexico, Texas, and Oklahoma the crop matured under favorable conditions and yields well above normal were obtained. Heavy rains in western Kansas preceding and during heading caused a rank growth of straw and favored the development of leaf rust and other diseases. Lodging and rust, together with a hot, dry period which came during the latter part of June, caused the yields of many fields to fall far below the early estimates, but in general the returns in Kansas were fairly satisfactory.

As this is a meeting of agronomists, it is in order to discuss briefly the conditions which led to the widespread crop failures and their probable effect on the future development of the two districts. The southwestern district, which includes the western half of Kansas, the western half of Oklahoma, the Texas Panhandle, and a few counties in northeastern New Mexico, embraces much territory not usually considered safe for the growing of wheat. Because of the high price of wheat in 1917 and 1918 and also because of a patriotic desire to increase food production, farmers in this district greatly increased their wheat acreage even tho weather conditions at seeding time in 1916 and 1917 were distinctly unfavorable. The available moisture was insufficient for normal germination and growth and, as a consequence, losses from soil blowing and winterkilling were excessive. The drouth continued during the growing seasons of both 1917 and 1918, so that the comparatively small acreage which survived the winter produced small yields. The high price of wheat led farmers who usually devoted considerable acreages to feed crops such as corn and the grain sorghums to increase their wheat acreages materially at the expense of these crops and the usual proportion of fallow. The winterkilling of wheat left land vacant for feed crops, but the rainfall was insufficient for normal yields.

The good returns from wheat in 1919 have enabled farmers in the Southwest generally to recoup in large part the losses incurred during the previous two years. The indications now are that the funds received from this wheat crop are being used for the payment of debts, the purchase of livestock, and for other purposes which will result in lasting benefit to the agriculture of this district. Altho conditions were again favorable for the sowing of wheat over most of the southwestern territory in which loans were made, reports indicate a decided reduction in the acreage as compared with that sown a year ago.

This is due to the exorbitant wages demanded by harvest hands, to difficulties and losses met in marketing the crop because of an insufficient supply of cars for shipment, and to uncertainty regarding the price of the 1920 crop. It is due also in large part to the very general campaign for conservatism in the sowing of wheat and for an increase in the acreage of sorghums and other drouth-resistant crops suitable for feeding to livestock.

In western North Dakota and in Montana, farmers had also strained every resource to sow the maximum acreage of food grains during 1917 and 1918. The conditions caused by the general drouth in western North Dakota and in northern Montana during these two years were aggravated by serious losses from the rust epidemic which greatly damaged the wheat crops in western North Dakota and in a few counties in eastern Montana in 1916, and by grasshopper damage, particularly to flax, in western North Dakota in 1917 and 1918. A considerable part of the affected area in Montana was public land recently opened for settlement, so that in many cases farmers had not yet completed proof on their homesteads and therefore were unable to obtain funds by mortgaging their land. These people had settled in Montana in 1916 or 1917 and had not produced a profitable crop since their arrival in the State. Others who came earlier had been misled by the abundant crops harvested in 1915 and 1916 and, on the assumption that yields of 40 bushels or more of wheat could be expected each year, had expended the proceeds in improvements on their land, in the purchase of additional acreages, or in other ways, so that they had little to fall back on when disaster came.

For the first time since weather records have been kept in western North Dakota and in Montana, three dry years have occurred in succession. Not only have farmers suffered from the cumulative effects of the drouths of 1917 and 1918, but the drouth in 1919 was more severe and widespread than that of either previous year. Tho the average rainfall in this region is less than in western Kansas and western Oklahoma, the normal summer temperature and the evaporation are usually much lower, so that the precipitation is decidedly more efficient. In the judgment of men who know conditions in both sections, the chances of producing a profitable wheat crop in Montana and western North Dakota are better than in western Kansas and western Oklahoma, but this year the farmers in Kansas and Oklahoma gambled with the weather and won, while those in Montana and southwestern North Dakota gambled and met a most disastrous loss.

As a result, a considerable number of the farmers have been com-

pelled to leave their farms temporarily and secure employment elsewhere to support their families. Much of the livestock has been sold, and the purchase of feed and forage at high prices has been necessary to maintain that which was retained. The courage of the farmers, however, is remarkable, and only a very small percentage is leaving the farms permanently. The successive drouths have caused great interest in irrigation, particularly in Montana, and probably the irrigated acreage will be greatly increased within the next few years. An increased irrigated acreage will not only stabilize Montana agriculture, but will be of great benefit to the dry farmers, as it will insure an abundant supply of forage for use in dry years and a market for surplus stock.

In my opinion, dry farming has a future in western North Dakota and Montana, but it must be based largely on farm units of at least 640 acres and an increased production of livestock. For the most part this livestock will be pastured on native range, but will be maintained thru the winter and thru periods of temporary drouth by the use of forage crops such as corn, sunflowers, and sweet clover. A considerable acreage of wheat and other small grains will continue to be grown, but the main dependence of the farm will not be on these crops.

A discussion of Federal seed grain loans would not be complete without an acknowledgment of the excellent cooperation rendered by the various State extension officials, county agents or other county officials who acted in their stead, officers and members of farm bureaus, and local bankers. The county agents in particular are to be commended for their untiring efforts in connection with these loans. Without their aid, proper supervision in making the loans would have been practically impossible.

THE TEACHING OF ELEMENTARY SOILS.[1]

H. O. Buckman.

The teaching of soils in the systematic and fundamental manner in which recognized university and college subjects have long been handled is a comparatively recent development and as a consequence the possibilities are as yet only partially realized. As with all new subjects, soil science is going thru a definite evolution and will con-

[1] Contribution from the Department of Soil Technology, Cornell University, Ithaca, N. Y. Received for publication December 4, 1917.

tinue to so evolute until it is placed on as sound a theoretical and pedagogic basis as its subject matter will permit. In general, new subjects lack both data and arrangement. Soil science is no exception to the rule. At the beginning, little scientific knowledge was available and even that little had no logical sequence. Taught in many places as a part of agricultural chemistry, no distinct laboratory development resulted, especially regarding the physical phenomena.

The need for teaching data has been acute and while this need stimulated research, it forced the teacher for the time being into a very practical and applied consideration of his subject. Lectures, demonstrations, and field explanations constituted most of the instruction. The agricultural colleges were growing rapidly and expansion was expected at every point. The teachers of soil technology felt the pressure and as most scientific subjects are taught with laboratory practice, a move in that direction seemed desirable. The chemical phases were, of course, developed with chemical equipment as a basis. The physical side of the work was, however, much handicapped by lack of apparatus and methods. Due to the difficulty of controlling physical reactions in the soil, the exercises were always unsatisfactory and often crude. To a student with a good knowledge of elementary physics such laboratory practice was not only a waste of time but almost an affront to his general education.

The chemical phase of the laboratory took a different turn, and involved analytical chemistry was often taught in an attempt to give the student a chemical viewpoint of soils. Time was wasted in chemical methods and the attention thus distracted from considerations invaluable in understanding the "why" of practical farm operations. Chemical principles that may apply to soils are a part of the science of chemistry and should be taught in a department of chemistry and not in a department of agronomy or soils. Free use of such principles, however, is the right of every soil teacher.

The time has come when many feel the necessity of revising the teaching methods which have developed during the infancy of the subject. Plenty of sound data is at hand for such courses. It is not a question of knowledge but a question of arrangement and coordination. The pedagogy of the subject so long neglected needs attention. How to teach is the pertinent question, not what to present. Recent scientific and theoretical advancements have a proper place in the more technical courses offered by a department.

The science of the soil is now on such a basis that one general fundamental course seems preferable to the two or even three that are

in many places offered in as many calendar terms to cover the subject. Good pedagogy demands such a change. Geology has long been taught in such a manner, as have other pure sciences. Is soil science so different that ordinary procedure does not apply? Has it such a large body of facts that three lectures a week for a term will not permit a clear presentation of the fundaments?

The institution of recitation periods should be the next step. Here the principles explained and emphasized in the lectures can be expanded and discussed, preferably with a textbook as a basis. The old style laboratory "experiments" should be discarded and exercises substituted which emphasize fundamental points. In short, the whole course may be made a "follow-up," the recitations on the lectures and the laboratory on both. Few ideas not already explained in lecture or recitation should be introduced into the laboratory. The student should there be given a chance to handle, study, and experiment with the material previously discussed. The study of soil-forming rocks and minerals, the naming of soils, the estimation of organic matter, the testing for acidity, and the identification of fertilizers are only a few of the possible follow-up exercises. Such a correlation of lectures, recitations, and laboratory could not fail to raise the grade of the instruction, especially if the students are properly grounded in chemistry, general geology, and physics before registering for the course.

At present, the institutions that are seriously engaged in teaching soils are not closely enough in touch so that any of them realizes the problems which are confronting the others. Few opinions and views have been exchanged. The experiences of one institution, whether successful or otherwise, have gone for naught as far as the others are concerned. As a consequence, a conference for a thoro discussion of the points at issue seems not only desirable but almost a necessity. Such a conference would aid the science as well as the pedagogy of the subject.

INTRODUCTORY COURSES IN SOILS.[1]

R. S. SMITH.

In a recent number of this journal, Karraker[2] raised a number of interesting questions regarding the laboratory work usually offered in the first or general course in soils by our State agricultural colleges. The following specific criticisms are implied: The work is not sufficiently vocationalized; it lacks the qualities for imparting mental discipline most effectively; it lacks accurate control; and the results obtained in certain exercises are misleading. It is further stated that many of the fundamentally important processes cannot be reproduced in the laboratory and the question is asked whether the student should not be given the opportunity of getting the subject matter of the course without the laboratory work.

The present writer feels that efforts directed towards the improvement of any course, particularly an introductory one, should be based on a careful examination of the true purpose of the course as a whole. A less comprehensive effort is likely to fall short of attaining the maximum possibilities because of the lack of a clearly defined aim.

The purpose of an introductory course may be tentatively stated to be not merely to impart information, but also to enlarge the student's vision and stimulate and illuminate his thinking. The full accomplishment of this purpose even by a well-equipped and enthusiastic instructor who has an abiding faith in the value of the work he is giving is probably impossible, but it may be attained with more or less success by interspersing thruout the strictly instructional work glimpses into the history of the subject, appreciative mention of some of the men who have contributed to it in the past and of those who are now contributing, and by calling attention in a conservative way to some of the unsolved problems which still challenge the best abilities. The effort should be to inspire the student to enter new worlds of thought with enthusiasm and to give him an understanding of the fundamental principles which underlie successful practice and not simply teach him to handle soils so they will grow good crops.

[1] Contribution from the Division of Soil Physics of the Department of Agronomy, College of Agriculture, University of Illinois, Urbana, Ill. Received for publication November 21, 1919.

[2] Karraker, P. E. What is the value of the usual laboratory work given in general soils courses? *In* Jour. Amer. Soc. Agron., 11, no. 6, p. 253–256. 1919.

If the admittedly weak laboratory exercises in introductory soils courses are to be strengthened by revision, elimination, or addition in the most rational manner, their contribution to the attainment of the purpose of the work as a whole must be kept in mind and they must be made to conform to this purpose as well as to the best available knowledge. An examination of the true function of each part of a course must be made and efforts at the improvement of any part must be guided by a clear idea of its function.

As ordinarily given, the introductory soils course consists of two or three lecture periods, one recitation period, and one or more laboratory periods a week. The lecture work is the center or nucleus upon which the other parts hinge and affords better opportunity for stimulating interest than is afforded when it is replaced by textbook assignments and an increased number of recitations, tho it may not be as effective a method of imparting information as the latter plan. The recitation period is designed to aid the student in making the information presented in lecture or textbook a part of his experience. It is difficult to carry the inspirational features often present in the lecture work thru the recitation period, for its nature seems to demand a rigid insistence that the facts previously presented be assimilated by the student. The higher the scholastic quality of the class, the easier it is to measure up to the general purpose of the course, as above outlined, in the recitations. It seems to the writer that it is unfortunate to term or think of the recitation hour as a "quiz" period. It should rather be emphasized as a discussion period, tho this does not imply the aimless and time-consuming discussion so dear to the heart of the lazy student.

The laboratory work is designed as a further aid to the student in visualizing and making real the fundamental principles brought out in the class room. It is exceedingly difficult to correlate the laboratory work properly with the lecture or textbook work, particularly in soil physics. Failure to accomplish this correlation results in the students performing the set exercises simply as a job to be done without an appreciation of their relationships. A confused state of mind results on the part of the good students and an attitude of indifference on the part of the poor ones. It seems fundamental to the writer that material which has not been treated in lecture or in textbook assignments should not be introduced in the laboratory, because of the apparently unavoidable confusion resulting. Whether this ideal can be fully attained in the soil physics course is a serious question, particularly when several periods a week are devoted to laboratory work. Altho the difficulty is great, its solution offers ample reward.

The subject matter of the laboratory exercises in soils courses has been questioned by Mr. Karraker. So far as the exercises lack accurate control or lead to false conclusions they are to be severely criticised. That they are not sufficiently vocationalized and fail to give the student "a knowledge and something of the art of doing operations which he will be using in post-graduation activity" does not appear to be an equally valid criticism. The educational value of any part of an introductory course cannot be judged by such a criterion, but must be judged on the basis of its contribution to the purpose of the course as a whole. If any given part cannot harmonize with and make a definite and real contribution to this general purpose, then the question may be legitimately asked whether this part should not be eliminated at least for certain groups of students.

The problems presented by the first soils course are difficult of solution. They are becoming constantly and rapidly more difficult, due to changes in the nature of the courses given in secondary schools. The need for improvement is general and must be met.

The purpose of this paper has been to state in broad terms a tentative outline of the general purpose to be attained by the introductory soils course and not to present a criticism of the many admittedly weak points. The need seems to be for something more than the improvement or elimination of certain laboratory exercises. Individual effort is always limited by the peculiar experiences and idiosyncrasies of the individual. Basic principles must be worked out and, if possible, agreed upon. To accomplish this the best collective effort of the men who are responsible for the teaching in the introductory soils courses is necessary. Efficient machinery must be set in motion for the definition of principles and correlation of the parts.

The writer ventures to suggest that an effective and feasible method of undertaking the improvement of our introductory soils courses which appears to be so generally needed would be for the American Society of Agronomy to select a group of men and instruct them to undertake a thoro study of the entire problem and make such recommendations as they saw fit. Such a group should define as clearly as possible the fundamental object to be attained by the courses and should also make a minute study of the means now employed or possible of employment in attaining this object. Great good would certainly result from the efforts of such a group in giving rational direction to the efforts of the instructor who may now feel almost lost among the growing difficulties with which he labors.

THE EFFECT OF ZINC IN SOIL TESTS WITH ZINC AND GALVANIZED IRON POTS.[1]

S. D. CONNER.

During the progress of some pot tests with acid soils, some unexpected results were obtained with the crops grown. After the first year, the unlimed soils became less productive. For instance, soils which grew fair clover the first year later would not grow buckwheat, a crop known to be much more tolerant toward acid soils.

The pots used were of zinc and galvanized iron, and were well paraffined to prevent the action of the soil acids upon the zinc. The results obtained, however, raised the question as to whether or not zinc had been made soluble and had penetrated the paraffine coating. With this point in view, tests were made and zinc was found in quite large quantities in the unlimed soils but not in the limed soils.

HISTORICAL.

In 1904, Veitch (8)[2] reported the presence of zinc in the sodium chloride solution of two acid California soils. Upon inquiry as to the character of these soils and the source of the zinc, Veitch later made the statement that the zinc came from pots and was not naturally found in the soils.

Haselhoff and Gossel (5) in 1904 reported that zinc sulfate was highly injurious to wheat and that the injury was not reduced by liming. Zinc oxide was not found to be injurious. This apparent contradiction might possibly be explained on the basis of a different degree of distribution of the zinc in the soil. The zinc sulfate, being soluble, might be much more widely distributed before fixation even in limed soil than was the insoluble zinc oxide.

Meyer in 1905 (6) found that crop yields were much greater in earthenware than in zinc pots, and that the injurious effects were largely overcome where lime carbonates were used. Tacke (7), in

[1] Contribution from the Department of Soils and Crops, Purdue University Agricultural Experiment Station, La Fayette, Ind. Read at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 11, 1919.

[2] Reference is made by figure in parentheses to "Literature cited," p. 64.

commenting on Meyer's article, says that the injury was heightened by acids dissolving zinc from the pots and that he had the same experience when experimenting with acid moor soils.

Ehrenberg (1) in 1908 reported work where he buried zinc plates in the soil. The zinc was found to be injurious, and ammonium salts caused increased injury. This would be in accord with the known action of ammonium sulfate in increasing soil acidity. Ehrenberg (2) suggested that different results with organisms in field soils and in zinc pots might be due to the interfering action of zinc salts. In 1910, he reported (3) beneficial results of zinc salts where nitrate of soda was used and injurious effects where ammonium salts were used.

Voelcker (9) in 1913 reported pot culture experiments where he found that zinc up to 0.01 percent in the soil was stimulating to wheat and above that was toxic.

Ghedroiz (4), in reporting experiments with acid soils in zinc pots, stated that clover made feeble growth in the third year. The bad effects were increased in the absence of lime. Clover grown in ebonite vessels showed no injury.

EXPERIMENTAL DATA.

Samples of five different types of acid soils which had been kept in paraffined galvanized pots for two and a half years were taken for the purpose of determining the percentage of zinc in both the untreated soils and from pots which had been heavily limed. The results are shown in Table 1.

TABLE 1.—*Percentage of zinc in acid soils from paraffined pots, with and without calcium carbonate.*

Soil.	Volatile matter.	Without lime.		With lime.[a]	
		Acidity, KNO_3 method.[b]	Zinc.[c]	Acidity, KNO_3 method.[b]	Zinc.[c]
	Percent.	*Pounds.*	*Percent.*	*Pounds.*	*Percent.*
Yellow clay	3.57	2,800	0.021	None	0.001
White silt	3.92	1,800	.013	do.	.002
Brown loam	7.45	840	.014	do.	.002
Black sand	10.13	2,520	.028	do.	.001
Brown peat	85.20	9,600	.088	600	.010

[a] The $CaCO_3$ added per 2,000,000 pounds of soil was, for the white silt and brown loam, 6 tons each; for the yellow clay and black sand, 12 tons; and for the brown peat, 40 tons.

[b] Pounds of $CaCO_3$ needed per 2,000,000 pounds of soil.

[c] Zinc soluble in cold normal KNO_3 solution.

In each unlimed soil, there was more than 0.01 percent zinc soluble in cold normal KNO_3 solution, the amount Voelcker (9) had found to be injurious to wheat in a loam soil which contained over 1 percent of lime. In no instance did a neutral sample of soil contain zinc in more than mere traces. The brown peat, which is of an excessively acid type, contained the most zinc and this soil, to which 40 tons of lime per 2,000,000 pounds of soil had beed added, was still acid and contained 0.01 percent soluble zinc, an amount approaching the danger line of toxicity.

Table 2 shows the relative yields of wheat and clover grown the first season and the yields of buckwheat and oats grown the last season on the two least acid of the five soils. The yields from the other soils are not given because they were very small, even with the first crops, on account of high acidity on the unlimed soils. On these soils fair yields of wheat and clover were obtained, in pots where smaller amounts of lime were applied, and later the buckwheat and oats failed almost entirely, undoubtedly because of soluble zinc.

TABLE 2.—*Average yields in grams of wheat and clover in 1917 and buckwheat and oats in 1919 grown in paraffined galvanized pots in acid and limed soils.*

Soil.	First year		Last year.	
	Wheat.	Clover	Buckwheat.	Oats
White silt	20 0	15.0	0.2	0.1
White silt limed	41 0	40 0	31.2	1 7
Brown loam	20.0	21.0	3.5	1.7
Brown loam limed	27 0	32.0	35 0	2.0

Whether a good protective coating can be found is a question remaining unsolved.[3] Until a satisfactory coating is found there can be no question that it is unsafe to use zinc-coated pots in soil tests with acid soils.

The pots used in these experiments were 9.25 inches in diameter and were watered by a subirrigating device on the order of the Wagner pot, so any injurious substance would have a chance to penetrate the soil quickly. Where large pots or rims are used and the water is applied at the surface it would undoubtedly take longer for the zinc to permeate the whole soil mass; hence, the injurious effects would be delayed.

[3] Dr. H. J. Wheeler has given the information that at the Moor Culture Experiment Station at Bremen, Germany, zinc pot's could not be used on account of the soil acids until they had received a protective coating. Wood tar applied with heat was the most successful material used.

In this connection it might be pertinent to point out that this action of acid soils on zinc is one more bit of evidence that soil acidity is chemical and not physical and that there are real acids in the soil and not mere selective absorption phenomena.

SUMMARY.

1. In pot tests with acid soils in paraffined galvanized iron pots, crops began to fail the second season in an unexpected way.

2. On testing the soils where the crops had failed, water-soluble zinc salts were found.

3. Tests of the soils showed that the zinc was present in injurious amounts in the untreated or insufficiently limed soils, but not in the soils where sufficient lime had been used.

4. The paraffine coating had been granulated and the soil acids and zinc salts had passed thru it.

5. No good protective coating has yet been found.

6. This action of acid soils on zinc is evidence that soils contain true acids.

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THE TRUFAST TEST FOR SOUR SOIL.[1]

ELMER O. FIPPIN.

The practical experience of farmers and the investigations of State and Federal agencies show that large areas of soil in humid regions need application of liming materials if their full productive capacity for many important crops is to be attained.

The chemical, physical, and physiological significance of this need for lime in the soil has not been made clear by the investigations conducted thus far. However, there seems to be a fairly good agreement among investigators that this need for lime is usually associated with, if not directly due to, a considerable degree of acidity in the soil. Acidity in this sense is perhaps best defined as the capacity of a soil to absorb calcium, sometimes called the lime absorption coefficient. Whether the capacity of the soil to absorb other bases than calcium bears a direct relation to its need for lime does not seem to have been determined.

It is well known that soils differ widely in their need for lime for the successful growth of some crops. The prevailing practice has been to associate this different need for lime with the presence of different amounts of active or free acid in the soil. Various tests are in use to measure the amount of this so-called acidity which is assumed to be correlated with the amount of lime needed by the soil for the production of crops sensitive to lack of lime in the soil. From the point of view of farm practice such methods of measuring the need for lime in the soil should be rapid, simple, and easily carried out either in the field or in close association with field conditions.

Without presuming to review the essential features or the advantages and disadvantages of existing methods for this purpose, we present a new method that has been devised to meet, as far as now seems possible, the dominant requirements of the problem of so-called acid or sour soils. This test is called the "Trufast" test, the manipulation and most of the essential features of the test having been devised by Mr. A. D. Whipple, who has been associated with the National Lime Association as its chemist and engineer. The underlying chem-

[1] Paper 3-20-2 from the National Lime Association, Washington, D. C. Presented before the twelfth annual meeting of the American Society of Agronomy, at Chicago, Ill., November 10, 1919.

ical principles employed are much the same as in other tests. The most distinctive features are the chemicals employed and especially the outfit and manipulation by means of which the test is made.

CHEMICAL PRINCIPLES EMPLOYED.

To bring the acidity of the soil into liquid suspension where it can be measured, the soil is suspended in a strictly neutral solution of calcium nitrate of sp. gr. 1.3 at 76° F. After suspension in 60 c.c. of this solution for five to ten minutes with thoro shaking, the mixture of soil and solution is filtered through a neutral filter paper and the first 15 or 20 drops of extract are rejected to correct for absorption of the paper. An aliquot portion of the soil extract, 15 c.c., is used for titration.

The alkali used in titration is a solution of sodium carbonate having a strength of $N/49.5$. The indicator used is methyl red, which does not react freely to carbonates.

SPECIAL FEATURES OF THE TRUFAST OUTFIT.

The amount of soil employed in the test is 6.166 c.c., which is one hundred-millionth of the volume of an acre 6 inches deep. This is approximately the volume of soil normally treated by an application of lime.

The sample of soil is measured by liquid displacement. A specially made cylinder is employed having a mark on the glass at 60 c.c., to which line the cylinder is filled with calcium nitrate solution. Soil is then added until the level of the liquid is raised to the level of a second line marking a volume of 66.166 c.c., or 6.166 c.c. above the first. All liquids are measured from the top of the meniscus to avoid error in turbid solutions. Vigorous agitation by shaking about 500 times is employed to break down granulation and permit free diffusion from the surface of the soil particles.

The second or titrating cylinder has a scale cut in the glass, the lower or zero line of which marks a volume of 15 c.c. from the bottom of the cylinder. This is the aliquot portion of the extract used for titration. The indicator is placed in the titrating solution in the proportion of about one drop to the cubic centimeter. The soil extract is titrated in the cylinder direct from the bottle, a few drops at a time, until any red color has been discharged and a neutral tint attained as shown by comparison of the color of the titrated extract with the color of the titrating solution when both are viewed against the light. At this point it is important to stop the titration as soon as

the last trace of red color disappears from the titrated column of soil extract as viewed laterally against the light and not attempt to discharge the residual pink color that may still be seen from the top of the solution column. The complete discharge of the end point color represents a strongly alkaline condition of the solution and not the neutral condition that is desired. The difference in depth of solution in the cylinder and the bottle must be taken into account in making this color comparison.

The number of cubic centimeters of alkali required is read direct from the scale, the strength of the alkali in comparison with the volume of the soil used being such that each scale division represents a lime absorption equivalent to 500 pounds of calcium oxide per acre 6 inches of soil. Every fourth division represents 1 ton and these are numbered from the bottom.

A test is ordinarily made in from 10 to 15 minutes. Samples will vary in the rate at which they filter. In running a series of samples the filtering and titration can usually be done as rapidly as the suspension of soil is prepared. In using calcium as the absorbed base the test is comparable with the liming material the farmer will use. Nitric acid is a normal constituent of soils and is only very slightly absorbed. In measuring the soil by liquid displacement, errors due to crumb structures are largely avoided. No heat is used. The necessity for all mathematical calculations is eliminated by the character of the outfit and the strength of the solution. The test reads directly in practical terms. The reading of calcium oxide may be readily converted into hydrated lime by multiplying by the factor 1.35 and to carbonate forms of lime by using the figure 1.8 for pure materials or more for material of coarse texture or that is impure. Clear solutions are secured. The results of the test on soils rich in organic matter are consistent with the results in normal mineral soils.

No attempt has been made at an extended comparison of Trufast results with the results from other methods. That is left to official laboratories. The results of a few determinations are given in Table 1 to illustrate the character of the readings.

TABLE 1.—*Results of determinations of soil acidity by the Trufast test.*

	Trufast reading, pounds of calcium oxide per acre 6 inches.	Type of growth.
1. Cecil clay soil, Md.	2,300	Good clover
2. Cecil clay subsoil, Md.	2,700	do.
3. Cecil clay soil, Md.	3,000	Medium clover
4. Hagerstown silt soil, Md.	1,500	White clover inoculated
5. Volusia silt loam, N. Y.	4,500	Clover scarcely grows
6. Ontario loam, N. Y.	2,500	Good clover

These results give some idea of the character of the reading secured. In my judgment it is not reasonable to expect an exact agreement between the results from different methods that may be employed in view of the complicated chemical character of the soil.

Further, it is important to recognize that the readings from any method have not been shown to correspond directly with the amount of lime required by that soil for the best growth of any particular crop. The correlation of crop growth with the coefficient of lime absorption or acidity in a soil is a distinctly separate operation from determining the position of a soil on the acidity or lime-absorption scale. Methods of measuring acidity determine only the position of the soil on such a scale.

Each crop has a certain range of tolerance of this so-called acidity and also of free lime in the soil and this range appears to be different for different plants. Having determined the coefficient of calcium absorption of the soil the next step is to determine from the acidity tolerance of each crop the amount of lime necessary to bring the soil up to a condition for good growth of that crop, whether it means an alkaline, a slightly acid, or a moderately acid condition.

The determination of the range of tolerance of each kind and variety of plant as regards acidity or alkaline or lime condition of the soil, as determined by any standard method, is one of the important pieces of soil investigation yet to be carried out. This requires a method that combines with reasonable accuracy of quantitative measurement, such rapid, simple manipulation as will permit the making of a very large number of determinations under all kinds of soil conditions, soil treatments, and crop growth. From such a mass of data we may hope to work out important correlations or possibly the lack of correlations with crop growth. The Trufast test is presented as a contribution to the means for working out these correlations if they exist.

A CHEAP AND CONVENIENT EXPERIMENTAL SILO.[1]

H. L. WESTOVER AND SAMUEL GARVER.

The utilization of certain forage crops for silage has been practiced for many years, corn being one of the first crops to be use in this way. In the early days of silage making, little was known regarding the ripening changes that took place in the silo and the conditions necessary for preserving the material properly were not well understood. As a result, the material that was put up frequently spoiled. At the same time, there was considerable disagreement among feeders as to the real value of silage from a feeding standpoint. As the conditions necessary for the proper preservation of silage became better understood and as a fuller appreciation of its true value as a feed developed, an increased demand for silage naturally followed. This eventually led to attempts to utilize other crops in this manner, particularly in regions where corn does not succeed and also in those sections where considerable spoilage results from unfavorable weather conditions at hay-making time.

Undoubtedly there are many plants, in addition to those at present being used, that could profitably be utilized for silage. In order to determine just what plants can be satisfactorily ensiled and under what conditions the best results may be obtained, some type of experimental silo is needed that will make it feasible to work with a large number of containers at a minimum cost. In the past, much of the work in trying new crops for silage has been with the farm silo, but this method is open to certain objections, the most obvious of which are the financial losses entailed when the contents spoil, as frequently happens, and the very limited number of experiments that it is possible to conduct.

Several State experiment stations have tried various methods for ensiling crops in small quantities and have reached the conclusion that silage in small containers is equal to that in large silos as judged by appearance and chemical analysis, where the conditions of ensiling are properly controlled. The silages made at these stations for experimental purposes fall into two general groups, chopped materials

[1] Contributions from the Office of Forage Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 10, 1920.

in small silos in quantities sufficient to test their palatability and feeding value in addition to studying the ripening changes, and chopped materials in tightly sealed glass jars and milk bottles for chemical and bacteriological studies, etc.

One of the early reports on the use of the larger experimental silos was made by the Wisconsin Agricultural Experiment Station for the year ending June 30, 1888. A bay in a barn was divided into six compartments, each 7 by 8 by 14 feet in size, but the materials placed in these silos did not come out in very good condition, and it was concluded that silage would not keep well in small silos. About twelve years later the Oregon station constructed several silos 9 and 10 feet in diameter and 22 feet deep. Other States that have more recently reported on the results obtained with small silos are Kansas, Missouri, and Idaho. The Idaho station used fir stave silos 3 feet in diameter and 6 feet deep, holding approximately 1,500 pounds. The Missouri station used cypress silos of the same capacity as those used by the Idaho station. These silos were fitted with covers, which at the Idaho station were weighted to insure proper settling of the contents, thus more nearly approximating conditions in a large silo. The silos used by the Kansas station were 7 feet in diameter and 16 feet high, with a capacity of about 10 tons. They were covered with a roof and as the contents did not settle satisfactorily the first year, the second season it was weighted with bags of sand to make conditions similar to those in the large silos.

Among the experiment stations that have reported results with smaller containers are Kansas, Iowa, Connecticut, and Wisconsin. In most cases these containers were 1-quart or 2-quart glass jars or milk bottles. The Wisconsin station, however, used containers ranging in size from one pint to several gallons, the larger ones sometimes being of galvanized sheet iron. The material was put up under laboratory conditions and was used in studying the ripening processes.

It is quite apparent that the larger experimental silos described above could be constructed in large numbers only at an expenditure of considerable time and money. The glass jars, on the other hand, in sizes generally used, are inexpensive, but, while they furnish sufficient material for laboratory studies, are of little value in determining the palatability and feeding value of any particular silage. What is really needed is a container that will permit putting up an almost unlimited number of silages at a minimum expense. It is believed that a method employed at the field station of the United States Department of Agriculture at Redfield, S. Dak., during 1919 meets this re-

quirement. After the experiment had been completed it was found that the same type of container had been used by the Illinois station at least as early as 1889, but in this case the main object of the experiment was to study the temperature changes in the silage and the size and character of the container was incidental. About the same time, the Vermont station reported the use of a circular wooden tank 3 feet high and 2 feet in diameter. Both these experiments were conducted so many years ago that they practically have been lost sight of.

The experiment was carried out at Redfield essentially as follows:

In August, 1919, a hand-feed cutter was purchased at a cost of about $20. This cutter was adjustable to cut materials in lengths of a half to one and a half inches and for this experiment was set to cut in seven-eighths inch lengths. This chopper met all the demands and not more than half an hour was required to chop enough material to fill each container.

The containers were motor oil barrels such as can be purchased at any garage, altho any strongly constructed barrel that is airtight and watertight would answer the purpose just as well. The cost of these barrels will vary somewhat at different times and places, but those purchased at Redfield cost $1.50 each. The heads are easily removed by loosening the two top hoops. The wood seems to have been treated in some way or else it is of such a character that the oils do not penetrate to any appreciable extent, as the barrels are easily cleansed with water. When the silage was opened it had no evidence of taste or odor of oil.

The chopped material was thoroly trampled as it was placed in the barrels and was heaped up somewhat so that it was necessary for a man to stand on the cover in forcing it on. When the cover was in place the hoops that had been loosened in removing it were driven back in place. The head was then covered with a thick coat of paint to exclude the air. In forcing the head in place some sort of a press such as is used in heading apple barrels would doubtless be more satisfactory than the method described above, as it would be possible to get a greater quantity of material in each container. With the method employed at Redfield, the contents of each barrel weighed from 150 to 200 pounds, the weight varying with the material used and the amount of trampling it received.

The materials ensiled in this way were alfalfa, sweet clover, corn, sorghum, sudan grass, Russian thistle, wild sunflowers, soybeans, one third corn and two thirds alfalfa, half sorghum and half alfalfa, and

half corn and half alfalfa. The alfalfa, corn, sorghum, one third corn and two thirds alfalfa, half sorghum and half alfalfa, and half corn and half alfalfa were put up on August 23; the other crops were ensiled on September 3. The barrels were opened on November 12 and 18 and all had a good appearance with the exception of the Russian thistle, which was dark and watery. Altho these feeds were tried on cattle unaccustomed to silage, all were eaten readily except the Russian thistle, which was refused absolutely, and the wild sunflower, which was eaten very sparingly by one cow.

It was apparent that the wild sunflower had not fermented properly. This was not due to the method employed, but probably to the presence of certain resinous substances, as the material retained the strong characteristic odor it had when put in the barrel. All the other silages except the Russian thistle had an excellent aroma and when small quantities were shipped into Washington and placed in glass jars in a warm room several of them remained in good condition for six weeks.

The results from this preliminary experiment were so satisfactory and the cost so insignificant that it is believed the method may be used advantageously in testing the keeping qualities of many plants, regardless of their apparent value for silage. There is almost no limit to the number of crops and combinations that may be tried under this method.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership of the Society as reported in the January issue was 561. This number included 61 whose membership actually lapsed on December 31 because of non-payment of dues for 1919. After deducting these lapsed members and adding 4 who have joined the Society since the last report, a net loss of 57 is shown, with a present membership of 504. It is hoped that a vigorous campaign for new members will be productive of results, and that many new members will be added during the next two or three months. With present high costs of paper and printing, a satisfactory Journal cannot be published unless the membership is very materially increased. The earnest cooperation of all members is solicited.

The names and addresses of new members, the names of those whose membership has lapsed, and such changes of address as have come to the notice of the officers, follow.

New Members.

Bryan, Walter E., University of Arizona, Tucson, Ariz.
McGinnis, F. W., 2089 Carter Ave., St. Paul, Minn.
Odland, T. E., University Farm, St. Paul, Minn.
Patrick, A. L., Agronomy Dept., State College, Pa.

Lapsed Members.

Agee, John H.,
Alvord, Emory D.,
Beavers, J. C.,
Bennett, Chas. D.,
Berry, Roger E.,
Bledsoe, R. Page,
Bower, H. J.,
Brandon, J. F.,
Bryant, Ray,
Bugby, M. O.,
Burtis, Earl,
Bushey, A. L.,
Cocke, R. P.,
Cooper, M. L.,
Cowles, H. C.,
Daane, Adrian,
Emerson, Paul,
Firkins, Bruce J.,
Freeman, Geo. F.,
Furry, R. L.,
Gericke, W. F.,
Gilbert, M. B.,
Hallsted, A. L.,
Hardenburgh, E. V.,
Hatcher, Otto,
Hildebrand, E. B.,
Horton, Horace E.,
Hotchkiss, W. S.,
Hungerford, DeF.,
Hunnicutt, B. H.,
Iberico, Juan R.,
Igo, Jerome,
Johnson, D. R.,
Jones, J W.,
Kan, F. F.,
Kelly, E. O. G.,
Kirk, N. M.,
Knight, Chas. S.,
Krall, John A.,
Kuska, J. B.,
Lynde, C. J.,
McHenry, Norris,
McMiller, P. R.,
Maier, Fred,
Maris, Edwin L.,
Milton, Roy H.,
Morgan, J. O.,
Olson, P. J.,
Peterson, W. A.,
Ruzek, C. V.,
Schmitz, Nickolas,
Sieglinger, J. B.,
Stokes, W. E.,
Turner, A. F.,
Veach, C. L.,
Voorhees, John H.,
Waller, Allen G.,
Walter, E. J.,
West, J. T.,
Winters, R. Y.,
Wyatt, F. A.

Changes of Address.

Fergus, E. N., Dept. Agron., Univ. of Kentucky, Lexington, Ky.

NOTES AND NEWS.

D. A. Brodie, who has been connected with the Federal office of Farm Management since 1903, on January 1 became agriculturist for the Western Sulphur Co., with headquarters at Cheyenne, Wyo.

F. M. Clement has been appointed dean of the faculty of agriculture of the University of British Columbia, vice L. S. Klinck, now president of the University.

A. D. Ellison, scientific assistant in charge of cereal experiments on the Belle Fourche Experiment Farm, Newell, S. Dak., resigned November 30 to become county agricultural agent of Butte Co., S. Dak.

F. V. Emerson, geologist of the Louisiana station and in charge of soil survey work in the State, died October 11.

A. E. Grantham, head of the department of agronomy in Delaware College and agronomist of the Delaware station for the past twelve years, has resigned, effective February 1, to become manager of the agricultural service bureau of the Virginia-Carolina Chemical Company, with headquarters at Richmond, Va.

Thomas Jahne and R. R. Mulvey are now assistants in soils in the college of agriculture of Purdue University.

Ove F. Jensen has resigned his position with the department of agronomy, Iowa State College, and on December 8 became midwest agronomist for the Soil Improvement Committee of the National Fertilizer Association, with headquarters in Chicago.

Bradford Knapp, for the past several years in charge of extension work in the Southern States for the United States Department of Agriculture, has resigned effective January 15 to become dean and director of the Arkansas college and station, succeeding Martin Nelson.

Theodore E. Odland has been made assistant in agronomy and J. E. Chapman has been elected assistant in soils in the Minnesota college of agriculture.

George A. Pond is now assistant professor of farm management in the Minnesota college of agriculture.

Robert R. Smith has been elected agronomist of the Northwest Experiment Farm, Crookston, Minn.

J. L. Snyder, president of the Michigan Agricultural College from 1896 to 1916, died during the last week of October at his home in Michigan. He was born in Butler Co., Pennsylvania, in 1859 and was a graduate of Westminster College. He was president of the Michigan Agricultural College during the period of its greatest prosperity and growth.

Dr. Simon Fraser Tolmie is the new Canadian Minister of Agriculture. Dr. J. H. Grisdale, director of the Central Experiment Farms and acting deputy minister, has been made deputy minister of agriculture, and has been succeeded as director by E. S. Archibald, formerly animal husbandman at the Central Experiment Farms.

F. L. Wagner of the Bureau of Plant Industry has succeeded George S. Knapp as superintendent of the Garden City, Kans., substation, Mr. Knapp having resigned to become State irrigation commissioner.

C. B. Waldron, dean of the North Dakota college of agriculture, is on leave for a year to act as director of agricultural education in the United States army.

F. S. Wilkins, who has been assistant in agronomy at the Oregon college since July, has returned to Iowa State College to take charge of forage crop experimentation, succeeding O. F. Jensen.

E. L. Worthen has resigned as associate professor of agronomy in Pennsylvania State College and has been appointed extension professor of soil technology for 1919–20 at Cornell University, vice E. O. Fippen, who is on a year's leave of absence.

A National Farm Crops Improvement Association was formed on December 2, 1919, at the Stock Yards Inn, Chicago, during the International Live Stock and Grain Show. The object of the organization is to promote the work of the various State crop improvement and experimental associations. Meetings will probably be held annually in connection with the International Live Stock and Grain Show. Prof. R. A. Moore of Wisconsin is president; Prof. G. H. Cutler of Alberta, Prof. Manley Champlin of South Dakota, and Prof. John Buchanan of Iowa, vice-presidents; and Prof. J. W. Nicholson of Michigan, secretary-treasurer. The topics discussed at the meeting were: "What Should Constitute Pedigree or Purebred Seeds," by C. P. Bull of Minnesota; "Seed Inspection and Certification by Associations," by J. W. Nicholson of Michigan and B. S. Wilson of Kansas; "Official State Seed Inspection," by A. L. Stone of Wisconsin; and "Marketing Pedigree Seeds," by H. D. Hughes of Iowa. Each paper was followed by discussion.

Aid for National Research Council.

The National Research Council has issued the following statement which will be of interest to members of the American Society of Agronomy, as our Society has representation on the Council.

The Carnegie Corporation of New York has announced its purpose to give $5,000,000 for the use of the National Academy of Sciences and the National Research Council. It is understood that a portion of the money will be used to erect in Washington a home of suitable architectural dignity for the two beneficiary organizations. The remainder will be placed in the hands of the Academy, which enjoys a Federal charter, to be used as a permanent endowment for the National Research Council. This impressive gift is a fitting supplement to Mr. Carnegie's great contributions to science and industry.

The Council is a democratic organization based upon some forty of the great scientific and engineering societies of the country, which elect delegates to its

constituent divisions. It is not supported or controlled by the Government, differing in this respect from other similar organizations established since the beginning of the war in England, Italy, Japan, Canada, and Australia. It intends if possible to achieve in a democracy and by democratic methods the great scientific results which the Germans achieved by autocratic methods in an autocracy, and at the same time to avoid the obnoxious features of the autocratic régime.

The Council was organized in 1916 as a measure of National preparedness and its efforts during the war were mostly confined to assisting the Government in the solution of pressing war-time problems involving scientific investigation. Reorganized since the war on a peace-time footing, it is now attempting to stimulate and promote scientific research in agriculture, medicine, and industry, and in every field of pure science. The war afforded a convincing demonstration of the dependence of modern nations upon scientific achievement, and nothing is more certain than that the United States will ultimately fall behind in its competition with the other great peoples of the world unless there be persistent and energetic effort expended to foster scientific discovery.

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SELECTION IN SELF-FERTILIZED LINES AS THE BASIS FOR CORN IMPROVEMENT.[1]

D. F. Jones.

Introduction.

The way in which domesticated animals and cultivated plants have been brought to their present condition is, for the most part, unwritten history. In the chief crops and most valuable animals the changes which have taken place during their amelioration have been vast. Selection, following up more or less intentional and unintentional hybridization, is the agency mainly responsible for these great advances.

Selection has been practiced in different ways. At the start primitive man chose forms from the wild which suited his need or fancy. This selection involved nothing more than the appearance of the individuals chosen. Selection based solely on appearance remained the only method until recent times and is still largely in vogue today with many plants, particularly Indian corn or maize, the most valuable plant in the Western Hemisphere.

Animal breeders as a rule have been more progressive than plant improvers. In the eighteenth century, when the great breeds of cattle, horses, and swine began to assume their present familiar forms and patterns, there was a far-reaching change in the method of selection. This innovation was the pedigree record system. The essential purpose of a pedigree system is to make possible selection based upon performance. When the characters and capacity of the ancestors and of the progeny as well as of the individuals themselves were

[1] Contribution from the Connecticut Agricultural Experiment Station, New Haven, Conn. Received for publication November 28, 1919.

taken into consideration, progress was immediately made more certain, judging from the quick rise to popularity of the Shorthorns, Herefords, Percherons, Southdowns, Berkshires, and other familiar breeds. The names of Blakewell, Colling, Bates, Booth, Tompkins, Price, and Hewer are well known and stand for skill in applying systems of mating based primarily upon ancestry and not appearance alone. To them, the ability to beget offspring with the desired characters and vigorous growth was of first importance.

When one considers whether or not these principles which have worked such marvels in the animal realm can be applied to plants he is faced with a different situation. Hermaphroditism, which is the rule with plants, introduces a complicating feature. However, many plants, of which corn is a good example, are continually and almost universally cross-fertilized naturally, so that for all practical purposes such plants may be looked upon as bisexual organisms.

The obstacles in the way of applying a pedigree record system, as used with animals, directly to the corn plant are so great as to render it wholly impracticable. To carry over the method unaltered one would have to select individual plants in the field before flowering time to be used as females and as males. Such plants would need to be artificially pollinated. The resulting progenies should then be grown in order to determine the relative value of the individual parents which were selected for mating. This would involve too great labor. What makes such a method still more hopeless is the fact that the chief character aimed at, production of grain, is not visible until after fertilization is accomplished. Therefore, it is not to be wondered at that the pedigree record system as applied in animal breeding has not seemed to offer much help to the plant worker.

The choosing of seed corn still proceeds in the primitive way of selection based solely upon appearance. The choice can be on only one side of the family, for no matter how excellent an ear of corn may be there is no way of judging the qualities of the plants which furnished the pollen to fertilize the seeds on that ear. Biometry tells us, however, that a sample of the hundred or so individuals representing the plants which supplied the pollen, taken at random from the field, will come close to the average of the whole population. In other words, one can be sure that the finest ear in any open-pollinated field of corn will have mediocre parentage on the staminate side. As a matter of fact it will be worse than mediocre because a random sample of pollen from a corn field does not of necessity come from the average producers of grain. Many plants which produce poor yields

supply pollen abundantly. Some plants in every field are wholly barren in pistillate parts but lack nothing in their staminate function. In general, there is a negative correlation in the development of the two inflorescences in corn.

The situation is exactly the same as if the animal breeder would turn his choicest dams loose upon the open range to be served by any sire happening to come along, a foolhardy procedure which is never tolerated. Yet the same method in corn breeding receives sanction and encouragement because no better method of selection has so far been available. By propounding elaborate score cards for judging seed corn, agronomists have thrown a cloak of pseudo-science over an antiquated system which is anything but scientific. Perhaps this is too severe an arraignment in view of the natural limitations imposed. In any case, there are abundant data from the work of Biggar (1),[2] Hartley (11), Hutcheson and Wolfe (14), Love (18), Love and Wentz (19), McCall and Wheeler (20), Montgomery (21), and Olson, Bull, and Hayes (24) to show that the correlation between the appearance of the seed ear, other than mere size, and the performance of the progeny is negligible.

To be sure, opinion has not been unanimous. Where correlations have been found, however, they are low and, when significant, have nearly always involved size relations where some association is to be expected. The same factors which enable the mother plant to produce a large ear tend to make the progeny large also. No one can reasonably urge that selection in field-pollinated corn is not worth while. Who would be so foolish as to recommend the planting of the poorest ears to be found in a field? The picking of the best-looking seed ears has undoubtedly had everything to do with the building up the varieties as they now are. But too close attention to details defeats the end chiefly sought—maximum production.

Corn breeders all along have recognized the great disadvantage which the unknown parentage on half of the family tree entails, and have endeavored to establish certain systems of selection based upon performance which would make possible a taking of the best from this unknown material. The various means of applying the ear-to-row method of breeding have been steps in the right direction, but they have never gone very far for the reason that selection is made after fertilization has taken place at random, whereas to hold out hope of real success judgment must be passed before the individuals are mated. Furthermore, the ear-to-row method has brought in a

[2] Reference is to "Literature cited," p. 98.

complicating feature. In every case there has been a narrowing of the network of related individuals which results in a loss of vigor. The good which might be accomplished by close selection is offset by reduction in size and rapidity of growth due to inbreeding.

What is needed at present is a different viewpoint, a radical change in method, and an application of sound principles, already proved in animal breeding experience, adapted to the peculiar conditions which hermaphroditism involves and which will obviate the disastrous effects of inbreeding. A new system is desired which is workable, which will make improvements permanent, and which will hold out hope for continued betterment. Before outlining what the writer believes is a beginning of such a system, it is necessary to sum up briefly present theories in regard to the significance of inbreeding and the results of actual experiments involving relationship matings.

Significance of Inbreeding.

The fact of reduced size and lessened vigor resulting from consanguinity, particularly in domesticated animals and plants which have previously undergone long periods of outcrossing, is beyond question. Due to Darwin's theories, this loss of growth ability has been looked upon as a natural phenomenon arising from an assumed physiological necessity for germinal mixing. The Knight-Darwin dictum that "nature abhors perpetual self-fertilization," like many popular slogans, has carried conviction but obscured the real point at issue. The practical stockmen have been closer to the true meaning of inbreeding than the biologists. The former have held that the effects of inbreeding, whether good or bad, were due to a concentration of like characters, favorable or unfavorable as the case might be.

The key to the solution of the problem was withheld until Mendel's theory of heredity became known. Segregation of recessive factors was seen to account for much of the evil brought to light by inbreeding, but segregation of independent Mendelian units was inadequate to explain the universality of the phenomenon. Recombination in a definite proportion of cases would bring all the favorable growth factors together in the pure breeding or homozygous condition, which would then be unaffected by any system of mating. As this was clearly not the case with many organisms, corn, for example, always being reduced by self-fertilization, it remained for the great extension of the knowledge of heredity which has taken place in the past ten years to make possible a logical interpretation of the whole problem.

The development of the chromosome theory of heredity, initiated by Bateson and Punnett in England in their studies on coupling of factors and carried forward with such remarkable success by Morgan and his school in this country, has shown conclusively that hereditary factors are carried in groups and that it is these groups of factors which mendelize. Because independent recombination within the groups does not occur, it is rarely possible to get all the more favorable characters collocated in one individual. Crossing, therefore, brings together the greatest number of different factors. As favorable growth characters tend to be expressed rather than unfavorable ones, whenever the two are paired, the complementary action of dominant factors furnishes a logical means of understanding the beneficial effects of crossing and the reverse results of close mating.

For the first time, inbreeding is viewed in a clear light. The results of this system of mating depend solely upon the inheritance received. Consanguinity in itself is in no way injurious. Like the detective who unearths a crime, it should be praised rather than censured. The important consideration is the constitution of the stock before close mating is practiced.

It is therefore not strange that some species should be naturally self-fertilized. Such forms came to possess fortunate combinations of all, or nearly all, the most favorable factors for development. Cross-fertilization could add nothing and was dispensed with. One should not confuse hybrid vigor with the important part that hybridization has had in evolution. Sexual reproduction certainly serves a very useful purpose or it would never have been established as the dominant method of propagation in nearly all forms of life. Exogamy, making possible a greater elasticity in adaptiveness to new conditions, is the primary importance of sexual reproduction. Hybrid vigor is a secondary result, however, of considerable value.

Results of Self-Fertilization with Corn.

Altho the evidence is convincing that consanguinity is not inherently harmful, one should not blind himself to the fact that the immediate results of close breeding in particular instances are very injurious or even disastrous. Take the case of corn. The fact that every time ordinary varieties of this crop have been self-fertilized a diminution in growth has taken place is established by the investigations of East (7, 8), East and Hayes (9), East and Jones (10), Shull (26, 27, 28, 29), Hayes (12, 13), Montgomery (22), Noll (23), and Jones (15). The reduction in size, however, proceeds to a cer-

tain point and then stops. Beyond that point there is no further change. The stage at which the alterations cease corresponds to the point where change in visible characters and reduction in variability also stop. In other words, a heterozygous complex is changed to a number of homozygous strains. Their form, size, characteristics, and ability to grow depend on the inheritance handed out to them as a chance allotment subject to the automatic elimination of the most unfavorable characters.

During this change to constancy, particularly in the earlier generations of self-fertilization, a great many characters appear which are clearly unfavorable to growth. Some of them cause the immediate extinction of the individual possessing them. To cite a few examples, there are several forms of chlorophyll deficiency more or less complete as indicated by pure white, virescent, and yellow seedlings. Other stages of chlorophyll reduction permit growth, but at a lessened rate, for example, japonica striping, green striping, fine striping, and golden chlorophyll color. Dwarf plants are commonly found in inbred strains of corn as well as many forms of partial or complete sterility of one or the other inflorescence or both. All these represent defective germ plasm. They may be expected in every field of corn and are quite commonly found, but in small quantities, due to the fact that constant crossing keeps them hidden from sight. Differences in height, in breadth and color of leaves, in size and shape of ears, and, in fact, in every detail of the plant structure are also segregated into different lines, so that when constancy is reached each strain is characterized by certain features which make it distinct from every other strain coming from the same original variety.

As these types isolated by inbreeding differ in external characters, so also do they differ in ability to grow. Theoretically, all possible levels of vigor may result from inbreeding. Plants may be isolated in the first generation which are incapable of reproduction. Other plants may theoretically be found which show no reduction in vigor at all. So far, no such plants have been discovered in ordinary varieties of corn, but they may be hoped for. The expectation can be diagrammed as shown in figure 4. The solid lines represent strains which have already been obtained; dotted lines show what may be found later. There may even be some lines which show an increased size and vigor resulting from self-fertilization. This follows from the fact that the factors combined in the heterozygous condition in ordinary corn probably do not show perfect dominance, so that when all the most favorable factors are combined together in

the diploid state a heightened growth efficiency may be expected. The chance for obtaining such strains in corn is exceedingly small, as will be shown later, but the possibility holds out hope for the maximum improvement of this plant.

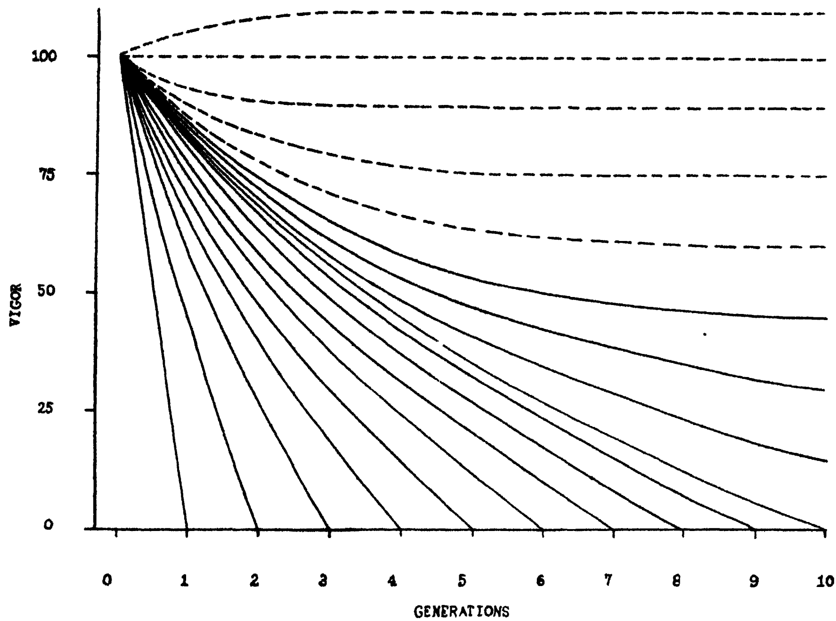

FIG. 4. Graph showing diagrammatically the actual and theoretical results of self-fertilizing ordinary varieties of corn. The solid lines represent strains already obtained which have either become extinct or have been reduced to 50 percent or less of the vigor of the original variety. The broken lines represent strains which can be expected theoretically when this plant is worked with more extensively.

Darwin (6) obtained self-fertilized morning-glories which were larger and finer than the original variety with which he started. Miss King (17) has secured inbred rats which are at least no less vigorous than the stock at the start.

The greater uniformity of inbred strains of corn is one of their most pronounced features. Table 1, in which the coefficients of variability of the original variety and several self-fertilized strains derived from it are given, shows how uniformity is obtained in measurable characters. This feature is even more noticeable in the details of the plants which are difficult of statistical expression, as seen in the accompanying illustrations (Plates 3 to 5).

TABLE 1.—*Variability of a variety of corn, of several inbred strains derived from it after ten generations of self-fertilization, and of crosses between these strains.*[a]

Pedigree No.	Coefficients of variability.			
	Height of plant.	Length of ear.	Number of nodes.	Rows of grain.
Original variety	8.81	19.07	10.07	14.22
1-6-1-3	4.95	18.16	5.66	7.88
1-7-1-1	8.29	19.52	7.41	8.74
1-7-1-2	8.00	19.69	7.35	9.23
1-9-1-2	6.39	11.55	5.89	7.65
(1-6-1-3 × 1-7-1-1) F1	6.42	19.39	5.73	8.75
(1-6-1-3 × 1-7-1-2) F1	4.95	14.72	4.99	8.09
(1-6-1-3 × 1-9-1-2) F1	5.59	13.09	5.33	7.94
(1-7-1-1 × 1-9-1-2) F1	8.01	16.79	6.15	10.24
(1-7-1-2 × 1-9-1-2) F1	6.49	19.29	5.89	9.60

[a] These figures have been compiled from Tables 4, 5, 6, 7, 18, 19, 20, and 21 of Conn. Agr. Expt. Sta. Bul. 207.

The way in which the approach to uniformity and constancy proceeds depends upon the system of mating practiced. It is most rapid in self-fertilization for the reason that when a plant becomes homozygous for any character it must ever after remain so. Brother and sister or parent and offspring matings are much less efficient for the reason that a homozygote may mate with a heterozygote. Thus, six generations of self-fertilization are more effective in producing homozygosity than seventeen generations of brother and sister mating.

The usual way in which an inbreeding experiment with corn is conducted is to select individual plants, self-pollinate them, and use one in each generation as the progenitor of the line. In that case, the rate of approach to homozygosity depends upon the constitution of the individuals chosen. Theoretically, a plant may be completely homozygous or completely heterozygous in every generation. The only thing which must follow is that no individual can be more heterozygous than its parent; it may be the same or less. On the average, however, there is a reduction of half the number of heterozygous allelomorphic pairs in each generation in self-fertilization. The reason for this may be made clearer by figure 5.

As an illustration, an organism heterozygous for 15 units is self-fertilized. The progeny of such an individual will be distributed in respect to the number of heterozygous and homozygous chromosome pairs according to the curve which resembles the familiar probability curve. The bulk of the individuals come at the center in the median grades of complexity. Therefore, an individual selected at random

FIG. 1. Plants of a continuously self-fertilized strain, showing uniformity in structural details, evenness in position of ear, and height of plant.

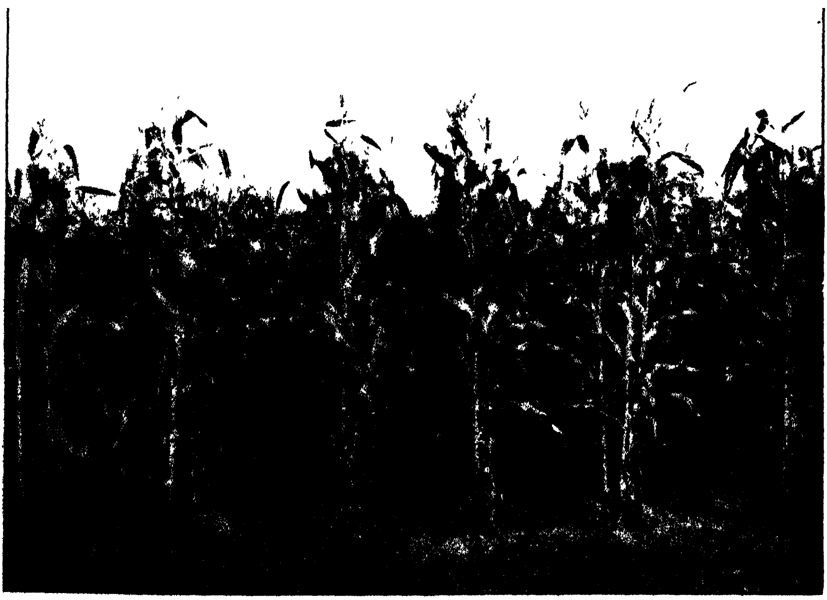

FIG. 2. First-generation crossed plants, showing that they retain the uniformity of the parent strains and are exceedingly vigorous.

FIG. 1. The uniform excellence of crosses between inbred strains, due to the fact that barrenness, degeneracy, and poor heredity in general have been largely eliminated, counts heavily in maximum production

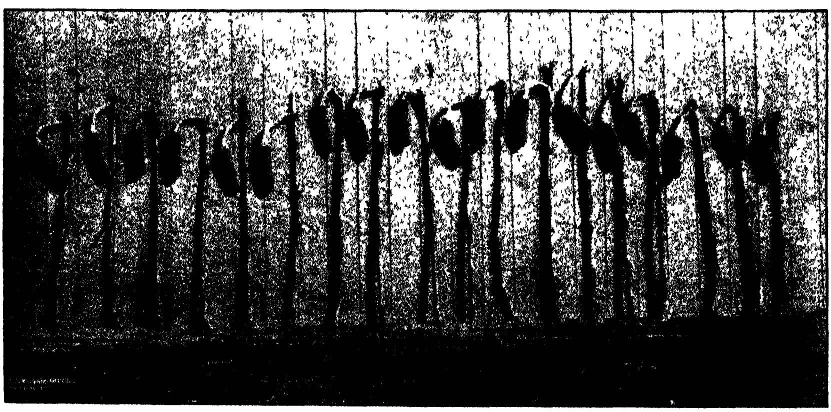

FIG. 2. The identical plants shown above, lined up for closer inspection. With one exception, the ears were placed at the sixth node, an indication of their remarkable trueness to form.

FIG. 1. Ears of a variety, two inbred strains derived from it after ten generations of self-fertilization, and the first-generation hybrid between these two strains, showing proportional yields in adjoining rows. The actual yields (left to right) were 96, 32, 20, and 115 bushels to the acre.

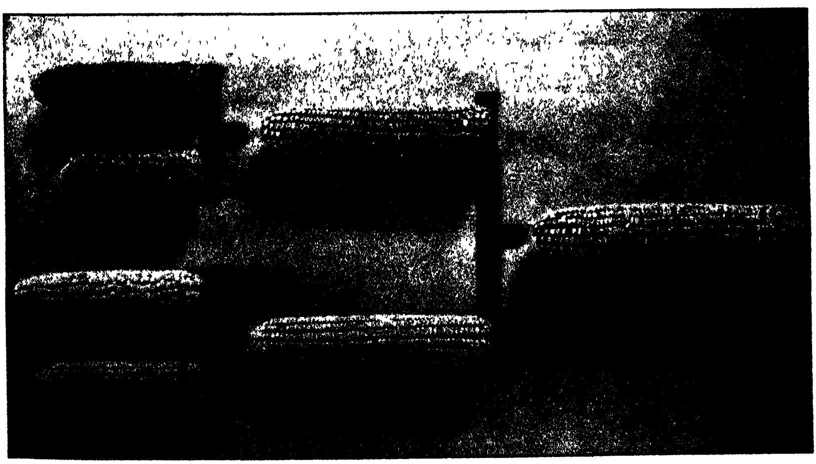

FIG. 2. Ears from inbred strains (left) and of crosses between them. This illustrates, from actual field results, the method of combining inbred strains to obtain maximum yields

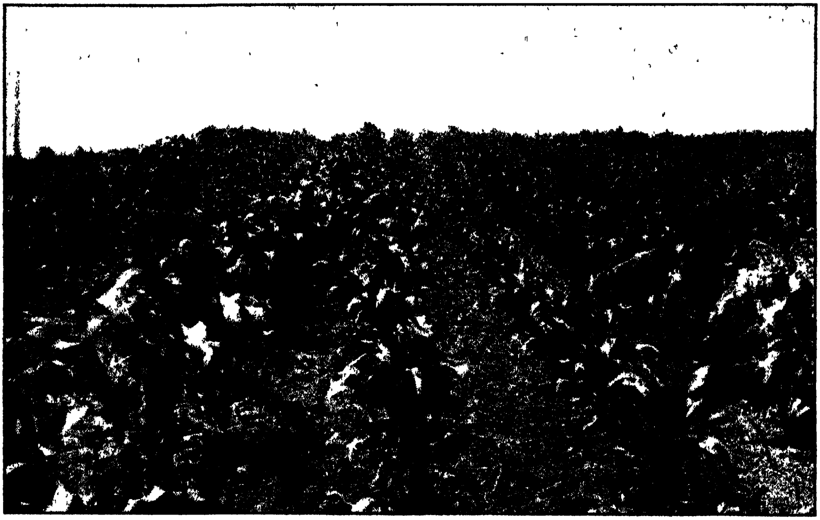

FIG. 1. The three rows in the foreground are the first, second, and third generations of a cross between the two inbred strains next to the left of the largest row.

FIG. 2. Plants from the rows shown in Figure 1, in the same order, showing that self-fertilization after crossing again reduces the plants to the level of vigor of their inbred parents.

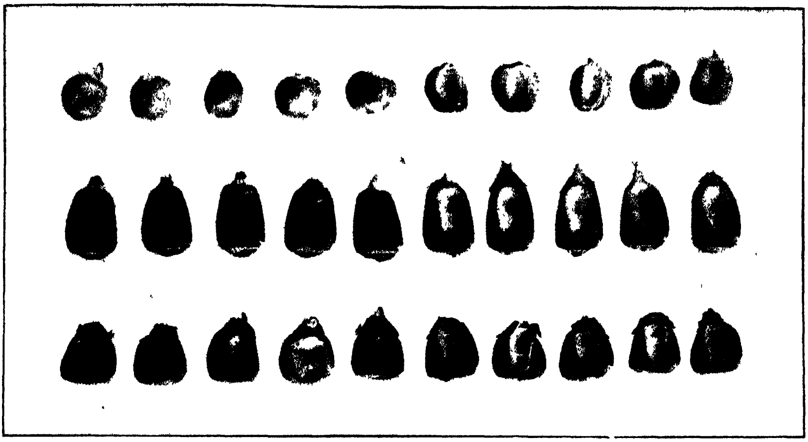

FIG. 1. Seeds from inbred strains (top and bottom) and from the first generation of a cross between them (middle). The first-generation hybrid between inbred strains is handicapped by its poor start, having to grow from small seeds borne on reduced inbred plants. The method of double crossing overcomes this advantage and plants starting from large, well-developed seeds like those shown in the center are capable of greater production.

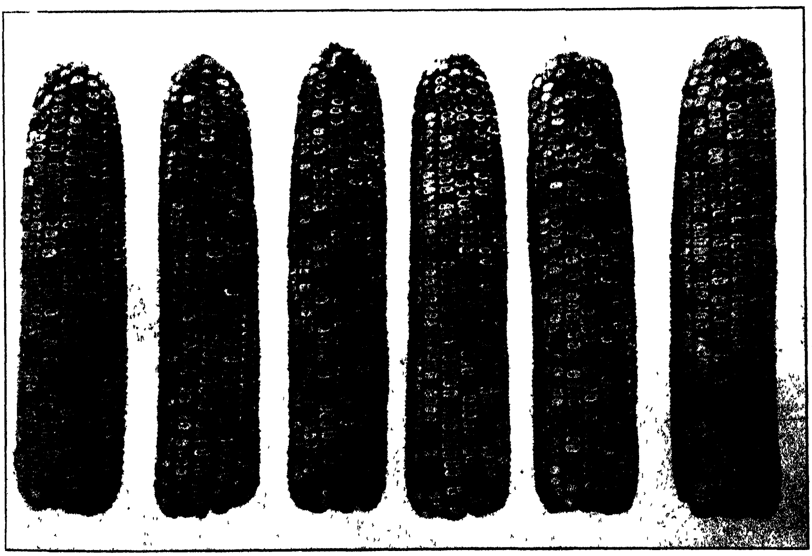

FIG. 2. Ears of a double cross which are nearly equal in size and are uniform, considering the great germinal diversity of such a complex hybrid. The specimens here shown were produced by pollinating a first-generation cross between two white strains with a cross of two yellow strains, as shown in Plate 5, figure 2. Similar results can be obtained with all yellow or all white strains, thus avoiding the mixture of colors on the ears.

to be the progenitor of the next generation, as a rule, will be half as heterozygous as its parent, and so on in each generation until complete homozygosity is ultimately obtained. Representing the homozygosity at the start as 0 percent, after seven generations of self-fertilization it will be 99 percent on the average and, after twelve generations, 99.9 percent. This is the theoretical expectation with independent inheritance. Linkage and differential viability enter as complicating factors. Actual results with corn show a very high degree of stability after six generations of self-fertilization and after ten generations no appreciable changes have been apparent.

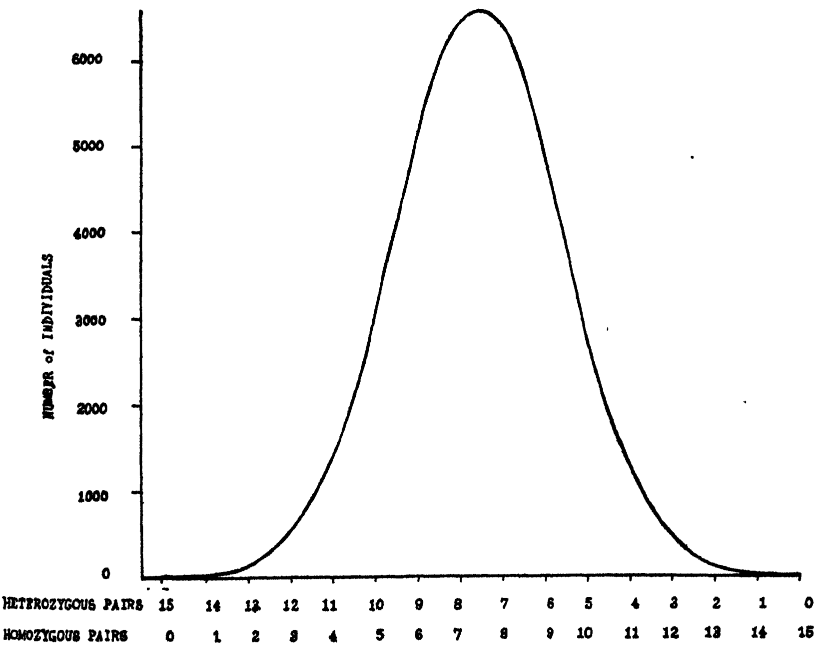

FIG. 5. Graph showing the theoretical distribution of the progeny of a self-fertilized organism heterozygous in fifteen allelomorphic pairs. The bulk of the individuals are in the central area. Any individual selected at random as a progenitor of a self-fertilized line will therefore most likely be about half as heterozygous as its parent. This will continue to be the case until homozygosity is obtained.

VALUE OF INBRED STRAINS.

The resultant plants which have been continuously self-fertilized until uniformity and constancy are reached have gone through a process of purification whereby much defective germplasm has been eliminated. Sterility is one of the first things eliminated. All other

markedly injurious characters soon fall by the wayside, due to the handicap they put upon the individuals possessing them. The result is that the surviving plants possess much of the best that was in the variety to start with, whether conscious selection has been practiced or not. Inbreeding removes the support which hybrid vigor supplies and each character must pass the rigid scrutiny of natural selection on its own merits. The result is beneficial. When inbred strains are crossed, vigor is at once regained and the uniformity of the parent strains is retained in the first generation of the cross. This is a very valuable feature which cannot be overemphasized. Not all combinations give equal results, but when a desirable cross is made its performance is very gratifying.

Picture a field of corn in which each plant is like every other plant and in which there are no barren plants, no abnormals or degenerates, where every member of the population is contributing an equal share towards the production of grain. Other things being equal and given a perfect stand of plants, a greater yield can be looked for from such a field than is possible by any other method of corn breeding now known. It does not take such a very large ear of corn to weigh a pound. Most ears of dent corn on exhibition in corn shows weigh somewhat more than this. It can easily be figured that an acre of corn with a perfect stand which produces even a half-pound ear on every plant will yield close to 100 bushels of grain. All plants are never exactly alike in practice, as not all plants have an equal opportunity to grow. Unfavorable situation, accidental injury, or disease may reduce the production on some plants. Given an equal opportunity to grow, however, with crosses of inbred strains the same results are obtained because all the plants are alike in hereditary constitution. Many crosses at the Connecticut Agricultural Experiment Station have yielded more than 100 bushels to the acre, outyielding all ordinary varieties grown on the same field.

Another point of great importance is that, with due allowance for seasonal variation, the same result can be obtained every time the particular cross is made. In other words, any improvement that is made is permanent because the parental strains are constant and give the same results every time they are crossed. Other secondary advantages are secured. If a certain cross is found good for a particular district, seed to produce that corn can be grown almost anywhere that corn can be successfully raised. For example, a cross giving excellent results in Illinois could be made in Pennsylvania or California and the seed continually produced there provided the

plants were properly grown and matured. If change in locality has any effect it is beneficial, as Collins' (3) results on new-place effect indicate. A further advantage lies in the fact that it gives the originator of valuable strains of corn the same commercial right that an inventor receives from a patented article.

SELECTION IN SELF-FERTILIZED LINES.

As inbreeding has been largely looked upon until now, it is a method of purifying stock automatically by freeing it of defective germplasm. There is no reason why it should stop there. What is most desired is a means of obtaining the very best that is in the material in hand. This is the aim of intelligent selection. Self-fertilization, by making possible a reliable estimate of the hereditary values of the male as well as the female parent, furnishes the best and surest means of gaining this desired result. Looked at in this way, the inbreeding and crossing of inbred strains as such is without particular value. As a system of breeding, however, selection in self-fertilized lines offers results in proportion to how extensively and skillfully it is used.

It is to be expected that not all crosses between inbred strains will give better results than the original variety. As a matter of course the bulk of the germplasm in every variety is commonplace. Of necessity, most inbred strains will have medium value. As will be explained later, the first-generation cross between inbred strains is handicapped at the outset of its growth. A means is at hand to overcome this. Even if many strains are found which give no appreciable increase in yield over the original variety, this does not vitiate the value of this method of selection, if sometime and somehow superb germplasm can be isolated which will give greatly increased yields. It then remains to compare the cost of producing the seed in the new way with the increase in yield obtained to decide whether or not the method is practicable.

Selection in self-fertilized lines makes possible the only thoro means of carrying on breeding with cross-fertilized plants, based upon performance and not appearance of the seed parent alone.

The application of this system to corn is exceedingly simple, altho it involves considerable tedious work. A tentative plan of procedure may be outlined as follows. From a number of plants of the variety to be worked with, individual plants are selected in the field for vigorous growth shortly before flowering and artificially self-polli-

nated.[3] It should again be emphasized that the chance for real improvement depends primarily on the extent of the material included. Let us take 100 self-pollinated ears to start with. About 20 percent of failures of hand pollination will occur, due to various causes, so that more than 100 plants will have to be pollinated artificially. We have found that two men can make about a thousand hand pollinations in a season of a month and a half. If many more than 100 plants of one variety are to be worked with it is necessary to plant at different times to extend the flowering period.

Starting with 100 self-pollinated ears of corn, each is to be planted the following year in a separate plat and again certain plants chosen for hand pollination. Five pollinations is the minimum number to make in each plat to insure a fair prospect of continuing the line safely. As grain production can never be properly judged before maturity, it is well to make as many pollinations as possible and select the plants to continue the line at the end of the season. Plant as many selfed ears in each line the following year as possible. Let us say three ears in each line are grown. As the plants grow in the field, it is possible in most cases to determine before flowering which of the three progenies is the best, so that only one of the three is chosen to be hand-pollinated to continue the line. From this, three hand-pollinated ears are again selected at maturity and the process is repeated until uniformity and constancy are reached. This can be expected ordinarily in about six generations, altho variations will be found. Selecting for the most vigorous plants will tend to perpetuate hybrid plants, as these give the larger growth. Much remains to be determined as to the best method of carrying on selection in this way. The procedure outlined may be diagrammed as shown in figure 6.

A modification of this method at the start has been suggested by Mr. B. H. Duddleston[4] of the U. S. Department of Agriculture, whereby a large number of naturally pollinated ears are selected and planted in an ear-to-row test, saving part of the seed of each ear. The remaining seed of those ears which gave the best results are planted the following year, certain plants hand pollinated, and selection carried on in some such way as outlined above. By this method one year is lost at the start, but the chances of including the best material in the plants at the beginning is greater.

[3] For rapid and careful work in pollination the writer has found nothing better than ordinary paper bags of the best quality, using 8-pound bags for the ears and 10-pound or 12-pound bags for the tassels.

[4] In a letter.

In the course of such a period of intense inbreeding there will be great loss of size and vigor. Many strains will become extinct because of sterility, dichogamy, or extreme weakness. Many such strains could be maintained by sib mating, but it seems better to adhere rigidly to self-fertilization alone. Any other procedure is merely putting off the day of judgment which all plants must pass sooner or later. Many strains will possess undesirable characters which will make it seem best to discard them. Here is a serious

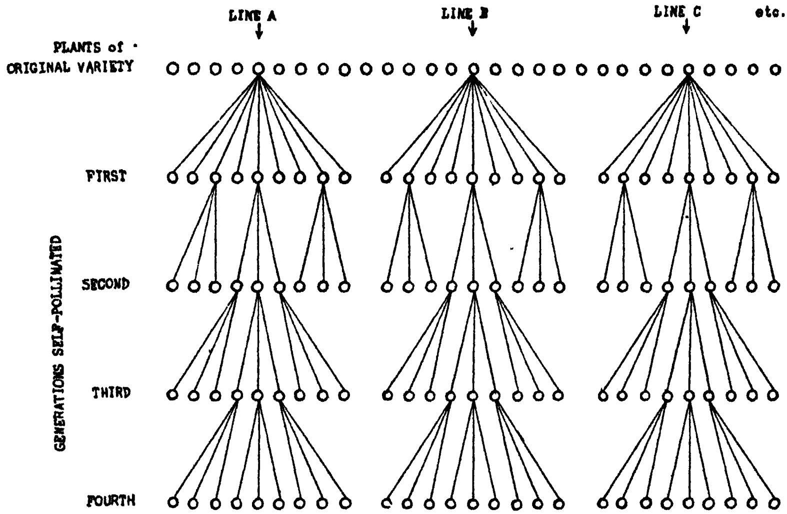

FIG. 6. Diagram showing the method of selection in self-fertilized lines. A number of plants of an ordinary variety are self-fertilized and each becomes the starting point for an inbred line. From the progeny of each certain plants are again self-fertilized and their progenies grown, but only one is chosen to continue the line. All the individuals in every generation in any one line trace back directly to the original progenitor.

problem which needs much more investigation. In general, there is a correlation between the productiveness of inbred strains and the crosses derived from them. This correlation is far from perfect, however, and some extremely poor strains give astonishingly fine results when crossed in certain combinations. Until we are more familiar with selecting in inbred material it seems wiser to keep all strains which are able to make fair growth until their value can be tested in combination.

The following are some of the most important qualities, in the opinion of the writer, for which to select:

Normal chlorophyll development generally indicated by dark green color with absence of striping.
Stocky plants with short internodes and well developed brace roots which stand perfectly upright thruout the season.
Bright colored, plump seeds.
Freedom from mold on the ear.
Freedom from parasitism on the plant or ear, particularly smut.
Absence of suckers.

Many other characters are important, but these named are suggestive. One of the most gratifying features of crosses between inbred strains is their freedom from mold on the ear. Inbred strains have been unconsciously highly selected for this behavior because ears enclosed in bags are very apt to become moldy. Many specimens are lost completely for this reason and of course cannot be perpetuated.

Some strains are also highly resistant to smut damage, as previously noted (16) and as shown in Table 2. This is a very valuable feature. Collins (4) also shows that corn can be made somewhat immune to ear-worm damage. It is possible that something can be done to reduce the damage from other serious pests of corn.

TABLE 2.—*Susceptibility to smut infection shown by four inbred strains of corn, by the original variety from which they were derived thru self-fertilization for ten generations, and by first generation crosses between some of these strains.*

Strain No.	1917.		1918.		1919.		Total.	
	No. of plants.	Smut infection.	No. of plants.	Smut infection.	No. of plants.	Smut infection.	No. of plants.	Smut infection.
		Per-cent.		*Per-cent.*		*Per-cent.*		*Per-cent.*
Inbred strain 1-6-1-3.....	992	0	1,000	1.00	144	1.39	2,136	0.56
Inbred strain 1-9-1-2.....	596	.34	559	.71	157	1.91	1,212	.69
Inbred strain 1-7-1-2.....	408	.49	307	9.12	145	4.14	860	4.19
Inbred strain 1-7-1-1.....	950	9.79	599	25.87	198	8.59	1,747	15.17
(1-6-1-3 × 1-9-1-2) F_1...	—	—	31	0	—	—	31	0
(1-6-1-3 × 1-7-1-2) F_1...	—	—	435	0	3,911	3.14	4,346	2.83
(1-6-1-3 × 1-7-1-1) F_1...	439	2.28	326	.61	—	—	765	1.57
Original variety..........	114	1.75	250	.40	119	7.56	483	2.48

UTILIZATION OF INBRED STRAINS.

After some degree of uniformity has been attained and there is no further drop in vigor it is necessary to test the surviving strains in all possible combinations with each other. After preliminary crosses have been made by hand pollination and tested in a limited way, the best of these can then be tried on a more extensive scale. The easiest way to do this is to use one strain as a pollen parent and plant all the

different lines in the same crossing plat, detasseling all but the one kind. If several such plats sufficiently well isolated from other corn are available and a different strain is used as pollinator in each, the testing can be done in a few years and the best combinations identified. As a general rule, reciprocal crosses will give about the same result. This is not always true, however, and this fact should be taken into consideration when making final choice.

When two inbred strains are combined, the first-generation hybrid plants are handicapped because of the small seeds from which they start, these having been grown on reduced, nonvigorous, inbred plants. Considerations are involved other than merely the amount of food material stored in the seed. Whatever the cause may be, it is apparent that the hybrid seedlings start off slower than seedlings of varieties or even second-generation seedlings grown from large seeds produced on F_1 hybrid plants, altho the F_1 surpasses the F_2 at the end of the season (15). This handicap is greater in some seasons than in others. Moreover, as most inbred strains are low in yield, the cost of first-generation hybrid seed to be used for general field planting is very great as long as inbred strains are used to produce such seed.

A method which overcomes both these objections is found in a cross of two first-generation hybrids of such genetic constitution that heterozygosity is not reduced and hybrid vigor is retained at the maximum. Such doubly crossed plants, starting from large, well-developed seeds grown on vigorous first-generation hybrid plants, are free from the handicap at the beginning of growth and for this reason yield more than the first crosses. Such a double cross must be made by combining four inbred strains which are all genetically unlike. They may all come from the same original variety or from different varieties. The essential point is that they should give good results when crossed singly in the several possible combinations. Even then it is not certain that the double cross will give the yields desired. This must be established by trial. A valuable combination once obtained, however, can always be had every time the same strains are united in the proper way. When two homozygous strains are brought together all the plants of the first-generation hybrid are exactly alike hereditarily. When two dissimilar F_1 crosses are again combined the result is a population in which nearly every plant is genetically different, to a greater or less extent, from every other plant. As regards development, each plant is essentially a first-generation hybrid because every chromosome pair is composed of unlike elements, the

parental strains presumably differing in all chromosomes. Practically no recombinations can take place which allow like factors to come together and weaknesses to appear. There is, however, great germinal diversity, so that the beautiful uniformity of a first-generation hybrid is sacrificed. It is largely the evenness in structural details which is lost; in ear formation and production of grain double crosses show a remarkable ability to yield. Ears used as parent strains in making a double cross, together with ears from the resulting hybrid, are shown in Plate 5, figure 2. Ears produced by such a double cross are shown in Plate 7, figure 2. Plants from the parent strains and the first-generation hybrids are shown in Plate 6, and kernels in Plate 7, figure 1.

Some idea of the chromosome situation in such a complex hybrid may be had from an illustration. If a first-generation cross between two self-fertilized strains which is heterozygous in three chromosome pairs, for example, as $A A'$, $B B'$, $C C'$, is crossed with another single hybrid having chromosomes of different constitution, such as $A'' A'''$, $B'' B'''$, $C'' C'''$, then the double cross will have various combinations of these chromosomes as: $A A'''$, $B' B''$, $C C'''$, or $A' A''$, $B B'''$, $C' C''$, etc. If there is no crossing over there will be 64 different combinations, but each association of chromosomes will be a heterozygous one. No like chromosomes are paired, therefore all plants are essentially first-generation hybrids. With ten chromosomes together, as in maize, with breaks in the linkage in unknown amount, the total number of possible types is exceedingly great.

The way in which such a double cross is put together is illustrated in the following diagram:

Variety

Inbred strains — A B C D

Single crosses — (A × B) (C × D)

Double crosses — (A × B) × (C × D)

The inbred parental strains when reduced to homozygosity after 6 to 10 generations of self-fertilization are constant and permanent. The double cross is not and if self-fertilized will go back to about the same level of vigor as the selfed material started with. If the cross is allowed to pollinate at will, in a few years it would constitute an

ordinary variety of about the same characteristics as the variety originally used.

In all this combining of strains one should not lose sight of the main principle involved. The crossing has no potency in itself. It is merely a short-cut method giving the best factors contained in the parental strains an opportunity of expressing themselves in complementary action. The value of the double cross lies solely in the good fortune which has attended the selection of the plants while they were being brought to homozygosity. It is there that effort and skill should be extended. Thoroness is also needed in discovering the best plan of bringing the strains together.

Certain incidental advantages make this method of double crossing more practicable than single crossing. First, the crossed seed for general field planting is produced abundantly and therefore cheaply. For example, inbred strains that yield from 20 to 40 bushels produce around 100 bushels per acre when crossed. As the seed is to be grown in a crossing plat where every alternate row is detasseled and the product of the detasseled row only used for planting, the double crossing method gives from 40 to 50 bushels of seed per acre, while the older method furnishes only 10 to 20, a difference which may easily determine feasibility. A second great advantage lies in the fact that incomplete detasseling of all the first-generation seed mother plants is not so serious as when inbred strains are used. As applied commercially it will no doubt be difficult to get 100 percent cross-fertilization in a crossing plat owing to some of the plants not being detasseled at the proper time. Plants of the F_1 generation give second-generation plants when pollinated with their own kind of pollen which are not markedly inferior to plants of the first generation. Selfed strains pollinated with their own pollen, instead of crossed as they should be, give inbred plants which are very poor in yield. Even a moderate number of such plants in a field of corn might nullify all the advantages to be obtained by crossing.

On the other hand, the complexity of the new method is a serious handicap. Four strains instead of two must be maintained. However, inbred strains are easily carried on after they have been brought to homozygosity. As all plants are exactly alike, it makes no difference whether they are cross-pollinated or self-pollinated within the strain. They can therefore be grown in an isolated plot and no extraordinary pains are necessary to exclude foreign pollen, for whenever outcrossing has taken place the resulting plants can be easily spotted the next year because of their greatly increased size

and can be removed before pollen is shed. In view of the great gain to be had it does not seem possible that the disadvantage of complexity will long stand in the way of the general utilization of this method of selection.

Carrier (2) has called attention to the increase in weight of seed immediately resulting from cross-fertilization as a method of increasing yield. The phenomenon of heterosis in both the endosperm and embryo has been well established. The stimulation is manifest in greater weight, higher specific gravity, and a more rapid rate of maturing. However, this effect is merely a by-product of hybrid vigor. If it is worth while to have heterosis working in the seed it is many times more desirable to have that stimulus in the plant, as it is there that yielding capacity is largely determined. As a matter of fact, increase in weight of seed due to cross-pollination is an indication that the plant is not working at its maximum. Mixed pollination between different inbred strains giving reciprocally crossed and selfed seeds on the same ears have shown increases in weight of crossed seeds of as high as 35 percent. Similar mixed pollinations made between two first-generation hybrids where the plants themselves were several times more vigorous than inbred strains have given much smaller increments in weight, ranging from 1 to 9 percent. A double cross, which has given the highest yield so far obtained, when pollinated with a mixture of its own and pollen from a very distinct source, gave no appreciable difference in weight of crossed seed.

Cross-pollination enters as a disturbing factor in varietal trials, but the effect works both ways and each variety has an equal chance to respond to the stimulus of hybrid vigor. However, cross-pollination tends to increase more the yields of the poorer yielding varieties and for that reason varietal tests are somewhat misleading. On the other hand, it is difficult to see how the tests can be conducted so as to avoid this, for, unless varieties are grown close together, differences in soil will more than offset any differences due to unequal effects of cross-pollination.

Comparative Cost of Crossed Seed.

Naturally, hybridized seed must sell for a higher price than ordinary seed. Corn is America's greatest crop. It produces more total value than any other plant grown in this country. It also produces a fairly large value per unit of area. Along with this the cost of seed in relation to the crop produced is far lower than that of most cultivated plants, as shown in Table 3.

TABLE 3.—*Comparison of cost of seed of some farm crops in relation to the returns.*[a]

Crop.	Quantity of seed per acre.	Market price per bushel.	Cost of seed per acre.	Average yield per acre.	Value of crop per acre.	Cost of seed as percentage of returns.
	Bushels.	*Cents.*		*Bushels.*		
Potatoes......	10.0	48.9	$4.89	109.5	$53.56	9.13
Wheat........	1.5	98.6	1.48	16.6	16.41	9.02
Barley........	2.0	54.3	1.09	25.8	14.00	7.79
Oats..........	2.0	43.8	.88	29.7	12.99	6.77
Rice..........	2.0	92.4	1.85	34.1	31.50	5.87
Beans........	.5	600.0	3.00	15.0	90.00	3.33
Corn.........	.3	64.4	.19	25.8	16.65	1.14

[a] The figures for the quantity of seed planted per acre are taken from Bailey's Cyclopedia of American Agriculture and those for market value and yield per acre are for the year 1914 from the United States Department of Agricultural Yearbook for 1914. A fair comparison on the basis of cost of seed is difficult because prices for all seed stocks fluctuate greatly. They are generally higher than the market price at which the crop is sold. At the same time, the market value is an average figure and furnishes a means of comparison, altho the cost of seed corn is usually somewhat more in proportion to market value than is the case with the other crops mentioned.

Is not the farmer fully justified, then, in trebling or quadrupling his outlay for seed corn if he can be reasonably certain of a 10-percent increase in yield as well as an improvement in quality due to a lessened amount of moldy grain? A crossing plat a half acre in size should furnish abundant seed for 50 acres. If the material to plant were furnished, the amount of time and effort expended on the crossing plat would be very little greater than that needed for searching a 50-acre field of corn for seed ears, as now practiced. A gratifying feature of such hybridized seed is that all the grain that is fully developed and properly matured can be used for planting. As all seeds are equivalent in germinal constitution, the scrubbiest ear in the lot is the equal of the handsomest. This is a novel situation that will require proof to convince most corn growers.

POSSIBILITY OF OBTAINING TRUE VARIETIES OF CORN.

The proposed method of selecting in self-fertilized lines and crossing in double combinations undoubtedly holds the greatest hope for the improvement of corn at the present time. The utilization of hybrid vigor, however, is a makeshift measure. It would be desirable to dispense with crossing altogether if possible. Theoretically, if all the factors contributed by the parental strains to make the hybrid valuable could be gathered together in one plant, that plant

would be the homozygous progenitor of a variety of corn which would be as stable as any naturally self-fertilized species, such as wheat, peas, beans, tomatoes, tobacco, etc. In fact, for the first time there would be a true variety of corn. So-called varieties of corn at the present time are merely germinal hodge-podges. What would be of greatest value is that such a variety would have no less vigor than the hybrid. Greater growth and productiveness are expected from such a homozygous type because dominance is seldom perfect. Duplex combinations are more favorable for maximum developmental energy than simplex relations, provided the same desired factors are all present in the former as in the latter.

For example, let us assume two inbred strains, each of which contributes four factors chiefly responsible for the increased vigor when these two strains are crossed. One has the diploid composition AA, CC, EE, GG; the other BB, DD, FF, HH. The hybrid is haploid in regard to each factor pair, viz., Aa, Bb, Cc, Dd, Ee, Ff, Gg, Hh. The fact that more different dominant factors are here present working together is the basis for interpreting the phenomenon of hybrid vigor. If these eight factors can be recombined into a homozygous instead of a heterozygous union which would be AA, BB, CC, DD, EE, FF, GG, HH, such a type should be appreciably more efficient in its life processes even than the hybrid. Such an organism would behave the same whether crossed or self-pollinated. In corn it would be a form hitherto unattained except possibly in one instance, but we may hope that such forms may be obtained. At least, every effort should be put forth in this direction. Investigational work along this line has great opportunities.

However, let us not deceive ourselves as to the magnitude of the task ahead. As yet no one can estimate the number of factor differences in corn concerned with growth vigor. Fifty definite hereditary units have been positively identified and more are being found. Many of these play no important part in development. Perhaps the number of factors really necessary for vital processes is not as great as now imagined. With only one factor in each chromosome group, there would be ten independent units, making necessary the growing of 1,048,576 plants in order to have an even chance of getting the one plant recombining all these factors in a homozygous state. With more than one factor in each chromosome, as there unquestionably is, the numbers necessary to work with are stupendous. Two factors in each chromosome so spaced as to have 10 percent breaks in the linkage with each other would necessitate 20^{20} individuals in the

segregating generation to have an even chance of securing the one plant desired. This number of corn plants would require an area roughly 3,700,000,000,000 times the area of the United States. Even if it were possible to grow this number, how could this one plant be identified so as to be protected from cross-pollination?

The immediate attainment of such homozygous plants with maximum vigor from ordinary varieties of corn is utterly impossible at the present time. More refined methods of genetic analysis are needed. Further knowledge of the factor relations in maize in regard to the location in the chromosomes is of the utmost value.

A hopeful sign is furnished by a variety of corn obtained from the southwestern Indians which has been self-fertilized by Collins for three generations and so far has shown no reduction in vigor. It is from just such isolated communities where the corn has probably not been outcrossed for long periods of time that such a state of affairs is to be expected. Natural selection has eliminated all but the most favorable characters. On account of isolation this corn has approached the condition of naturally cross-fertilized species which show no decrease in artificial self-pollination. What Nature has done with time as an ally we may be able to do by better methods of genetical analysis than are now available.

TABLE 4.—*Differences in number of totally barren plants as shown by the frequency distributions of test plats of corn.*[a]

Source.	Number of barren plants per plot.									Number of plats.	Ave. number of barren plants.	Percentage of plants, barren.
	0	1	2	3	4	5	6	7	10			
Varieties	4	3	5	6	7	2	2		1	30	3.03	2.53
Inbred strains	17		4		1		1	1		24	1.04	.87
Single first-generation crosses	42	4	3	2		1	1	1		54	.63	.53
Double first-generation crosses	28	12	5	4	1					50	.76	.63

[a] About 120 plants in each plat.

As continued self-fertilization automatically eliminates much undesirable heredity, it seems perfectly feasible to use inbreeding as a process of purification. After a number of homozygous strains of corn have been obtained they can be crossed among themselves and a new variety re-created with justified expectation that a real improvement can be effected. Such a variety would not be much different from the old one and would be but little more stable. With a great

[5] The number of combinations is calculated from the formula $r+1)^{n-1}]^{2c}$ where $r+1$ is the linkage ratio, in this case 10 percent or $9+1$, n is the number of factors in each chromosome, and c is the number of chromosome pairs.

deal of sterility, chlorophylll deficiency, and abnormal tendencies removed, however, the variety ought to be somewhat better able to grow and to produce. Table 4 shows how total sterility is removed by inbreeding. The results obtained will depend very largely on how extensively selection is carried on while the plants are being self-fertilized and after crossing. This is almost an untouched field for improvement and is equally applicable to all naturally cross-fertilized plants and bisexual animals.

Conclusions.

It is desired that thruout all this discussion of proposed methods for improvement the fundamental principle will not be lost to sight. This basic tenet is that selection in self-fertilized lines makes possible a reliable estimation of heredity values of both sexes. This has never heretofore been accomplished with corn.

When selection is made on as extensive a scale as the prospects for improvement justify, there is reason to believe that inbred strains will be produced which are much better than any that have so far been obtained. If it is possible to obtain self-fertilized lines only slightly less productive than ordinary varieties it may then be desirable to dispense with the method of double crossing outlined above and use only single crosses. Vigorous selfed strains when crossed should give practically as great yields as any double cross and would be more uniform and much easier to produce. The data collected at the Connecticut station indicate clearly that for the present the combination of two first-generation hybrids is necessary to secure maximum yields.

When, therefore, a method which is both commercially remunerative and scientifically exact is available, are the agronomists of this country going to be slow in applying it? The important need at the present time is extensive investigation aiming to make the system as workable as possible. Such investigation merits the intelligent interest and active support of all corn growers, seed dealers, and agronomists. This interest has not been lacking and it is to be hoped that corn improvement is now entering upon a new era.

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THE RELATION OF SIZE, SHAPE, AND NUMBER OF REPLICATIONS OF PLATS TO PROBABLE ERROR IN FIELD EXPERIMENTATION.[1]

JAMES W. DAY.

The data for the studies discussed in this paper were obtained at the Shelbina field of the Missouri Agricultural Experiment Station. The plat used was approximately one-fourth of an acre in extent and was apparently very uniform thruout. It was situated on the Putnam silt loam. In the fall of 1916, Fulcaster wheat was drilled at the rate of 5 pecks per acre in 100 rows 8 inches apart and 155 feet in length. The following June the wheat was harvested by hand in 5-foot row segments, and the yield of grain and of straw was recorded for each unit. There were, therefore, 3,100 units available for study.

A calculation was first made to determine the direction in which the greatest variation in yield existed. To indicate the variation that existed in the direction of the rows, the yields of the thirty-one series of 100 adjacent 5-foot row segments were compared. To indicate the variation across the rows, the yields of plats composed of three adjacent 155-foot rows were studied. The units of comparison in the two instances were of practically the same area. It was found that there was much greater variation across the rows than along them, or, in other words, the rows extended in the direction of least variation.

THE RELATION OF SIZE OF PLAT TO VARIATION IN YIELD.

A study was made of the relation of the size of plat to variation in yield. The standard deviation and coefficient of variability were

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The writer gratefully acknowledges the invaluable advice of Prof. C. B. Hutchinson, now professor of plant breeding at Cornell University, in planning the investigation discussed in this paper.

determined for each of many sizes of units that were formed by combining 5-foot row segments. The results are presented in Table 1.

TABLE 1.—*Data obtained on relation of size of plat to variation in yield.*

Size of plat.	Standard deviation.	Coefficient of variability.	Size of plat.	Standard deviation.	Coefficient of variability.
3 adjacent 155-ft. rows	5,885.40	14.19	5 adjacent 50-ft. rows	3,227.66	14.49
5 adjacent 155-ft. rows	9,022.00	13.07	10 adjacent 50-ft. rows	5,443.76	12.13
10 adjacent 155-ft. rows	13,018.31	9.43	15 adjacent 50-ft. rows	6,802.67	10.18
20 adjacent 155-ft. rows	19,405.81	7.03	20 adjacent 50-ft. rows	7,417.98	8.32
1 5-ft. row	164.84	37.20	30 adjacent 50-ft. rows	7,295.68	5.46
1 10-ft. row	262.89	29.58	50 adjacent 50-ft. rows	15,135.71	6.79
1 15-ft. row	354.07	26.52	3 adjacent 15-ft. rows	749.30	18.68
1 20-ft. row	434.67	24.41	5 adjacent 15-ft. rows	1,101.14	16.49
1 25-ft. row	518.07	22.81	10 adjacent 15-ft. rows	1,694.70	12.72
1 30-ft. row	602.27	22.53	20 adjacent 15-ft. rows	2,659.38	9.98
1 35-ft. row	661.48	21.32	50 adjacent 15-ft. rows	4,960.03	7.45
1 40-ft row	728.73	20.28	100 adjacent 15-ft. rows	3,688.95	2.77
1 45-ft. row	796.60	19.85	100 adjacent 30-ft. rows	6,326.87	2.38
1 50-ft. row	922.68	20.67	8 adjacent 5-ft. rows	595.02	16.77
1 60-ft. row	1,021.62	18.99	16 adjacent 5-ft. rows	869.78	12.36
1 75-ft. row	1,309.56	19.64	24 adjacent 5-ft. rows	1,120.85	10.54
1 100-ft. row	1,502.29	16.74	32 adjacent 5-ft. rows	1,238.05	8.74
1 125-ft. row	1,912.73	17.01	64 adjacent 5-ft. rows	1,599.08	5.66
1 150-ft. row	2,333.92	17.36	96 adjacent 5-ft. rows	1,786.46	4.20
3 adjacent 50-ft. rows.	2,186.24	16.37	100 adjacent 5-ft. rows	1,787.98	4.02

Table 1 shows the effect of increasing the size of the plat and bears out the accepted theory that in general an increase in the size of the plat increases the accuracy of the results obtained. It is evident from the data presented here that an increase of the size of the plat up to at least one twentieth of an acre will decrease variation, but that minor exceptions to this general truth occur in the case of very narrow long plats that run in the direction of least variation. It should be noted also that single plats of the maximum size used in this study, one twentieth of an acre, ordinarily do not reduce the variation to a point that will permit the detection of differences between varieties or fertilizer treatments.

THE RELATION OF SHAPE OF PLAT TO VARIATION IN YIELD.

Data on the relation of shape of plat to variation in yield are given in Table 2.

The data in Table 2 show that the shape of the plat has an important effect on the accuracy of experimental results. In each of the divisions of the table, plats of approximately the same area but of different shapes have been taken. The results show conclusively

TABLE 2.—*Data on relation of shape of plat to variation in yield.*

Units of which plat is composed.		Length of rows in plat.	Shape of plat.	Standard deviation.	Coefficient of variability.
No. of adjacent rows.	Length of rows.				
	Feet.	*Feet.*			
1	150	150	Long in direction of least variation	2,333.92	17.36
3	50	150	do.	2,186.24	16.37
10	15	150	Rectangular	1,694.70	12.72
24	5	120	Long in direction of most variation	1,120.85	10.54
5	155	775	Long in direction of least variation	9,022.00	13.07
15	50	750	do.	6,802.67	10.18
50	15	750	Long in direction of most variation	2,960.03	7.45
100	5	500	do.	1,787.98	4.02
10	155	1,550	Long in direction of least variation	13,018.31	9.43
30	50	1,500	Somewhat long in direction of least variation	7,295.68	5.46
100	15	1,500	Long in direction of most variation	3,688.95	2.77
3	155	465	Long in direction of least variation	5,885.40	14.19
20	15	300	Square	2,659.38	9.98
1	50	50	Long in direction of least variation	922.68	20.76
3	15	45	do.	749.30	18.68
8	5	40	Square	595.02	16.76
5	50	250	Long in direction of least variation	3,227.66	14.49
10	15	150	do.	1,694.70	12.72
32	5	160	Long in direction of most variation	1,238.05	8.74

that those plats having their greatest dimensions in the direction of least variation are more variable than plats that approximate squares in shape; and squares in turn are more variable than plats having their greatest dimension in the direction of greatest variation. That the more uniform results obtained in the latter plats are due entirely to the shape of the plat is borne out by the fact that in no case are these plats larger than the corresponding ones that lie lengthwise in the opposite direction.

The results indicate that where single plats of a given area are to be used, the greatest accuracy can be obtained from long narrow plats lying in the direction of greatest variation. In an experimental area that was as variable in its length as in its width, the shape of

the plat would exert no influence. When an investigator is unable to ascertain in which direction his soil is most variable, the use of square plats is probably advisable. If long narrow plats are used in such a case, the chances are even that they will extend in the direction of least variation and, therefore, be less reliable than square plats. A better method, however, consists in ascertaining the nature of the soil in a preliminary test and using long narrow plats that have their greatest dimension in the direction of greatest variation.

The data thus far presented indicate that it is possible to obtain fairly accurate results from single plats under certain conditions. On the area which forms the basis of these studies, however, no plat that was much below one twentieth of an acre in area or that had its greatest dimension in the direction of least variation gave a coefficient of variability of less than 2.5 percent. A series of plats each composed of 100 thirty-foot rows (see Table 1) gave a coefficient of variability of 2.38 percent. This variation is sufficiently low to indicate that a plat of such size and shape would give accurate results. The plat just mentioned was slightly less than one twentieth of an acre in area and extended 66.6 feet in the direction of greatest variation. It is probable that on an experimental area where the plats could be so arranged that the length in the direction of greatest variation could be increased much beyond 66.6 feet, while the plat width was decreased, a plat of even smaller area would give fairly dependable results.

THE RELATION OF REPLICATION OF PLATS TO VARIATION IN YIELD.

Data on the relation of replication of plats to variation in yield are presented in Table 3.

The effect of using a unit of comparison composed of systematically distributed parts is shown in Table 3. A comparison of the data in the first division of that table with those in Table 1 makes strikingly evident the fact that a unit composed of replicated rows gives more accurate results than a continuous unit of the same area. In every instance there was much less variation in units composed of replicated rows than in units of similar size composed of adjacent rows.

A comparison of the data in Tables 1 and 3 also justifies the conclusion that the same degree of accuracy can be obtained on a much smaller area when a unit composed of replicated parts is used. A study of the left half of Table 3 shows furthermore that as the number of replications of rows of a given length is increased, more accurate results are obtained, as also is the case when the number of

replications remains the same and the size of the parts replicated is increased.

TABLE 3.—*Data on relation of replication of plats to variation in yield.*

Composition of row unit.		Standard deviation.	Coefficient of variability.	Composition of block unit.			Standard deviation.	Coefficient of variability.
No. of rows.	Length of rows.			No. of blocks.	No. of adjacent rows.	Length of rows.		
	Feet.					*Feet.*		
3	155	3,972.75	9.58	5	3	50	2,654.38	3.97
5	155	3,663.36	5.31	10	3	50	4,481.34	3.35
10	155	5,992.95	4.34	14	3	50	6,549.04	3.50
15	155	5,820.50	2.81	5	5	50	3,277.14	2.94
20	155	7,835.50	2.84	10	5	50	5,309.54	2.38
3	50	1,590.41	11.86	7	5	15	2,343.53	5.04
5	50	1,657.22	7.43	14	5	15	3,087.07	3.32
10	50	2,651.13	5.95	28	5	15	3,395.89	1.83
15	50	2,934.72	4.39	3	10	15	2,385.96	5.97
20	50	3,939.99	4.42	7	10	15	3,486.28	3.75
30	50	4,550.91	3.40	14	10	15	3,080.94	1.66
60	50	5,497.99	2.06	3	20	15	3,584.34	4.51
3	15	539.03	13.43	6	20	15	2,016.34	1.27
6	15	923.25	11.52	3	50	15	10,566.53	5.29
12	15	1,217.31	7.59	5	8	5	1,334.90	7.53
18	15	1,542.75	6.42	10	8	5	1,541.28	4.35
26	15	1,428.38	3.97	52	8	5	2,077.35	1.13
52	15	2,197.54	3.05	5	16	5	1,530.27	4.32
78	15	3,177.47	2.89	7	16	5	1,936.41	3.90
104	15	3,383.64	2.35	9	16	5	2,132.85	3.34
156	15	3,984.77	1.85	14	16	5	2,857.67	2.88
				18	16	5	3,123.77	2.45
				36	16	5	1,679.44	0.66
				5	100	5	4,456.79	2.00
				5	3	155	10,183.75	4.92

In the right half of Table 3 are shown the data obtained by replicating blocks that contain three or more rows or parts of rows. This material proves that in general the conditions that apply to the replication of rows are also applicable to the replication of blocks. Replicated blocks invariably gave more accurate results than the same area in a single block. The same degree of accuracy was obtained on a smaller area when replication was employed. As the number of replications of blocks of a given area was increased, more accurate results were obtained. Where the number of replications remained the same, an increase in the size of the block replicated decreased the coefficient of variability.

The data also show that the best shape of block for replication is that which gave the best results with single plats, that is, a long narrow plat with its greatest dimension in the direction of greatest variation. Five replications of three adjacent 155-foot rows, for example,

gave a coefficient of variability of 4.92 percent, while five replications of a plat 5 feet in width and running entirely across the experimental area gave a coefficient of variability of 2.00 percent. The areas of the two series were approximately the same, but in the first case the greatest dimension of the individual blocks was in the direction of least variation, while in the second case it was in the direction of the greatest variation.

CONCLUSIONS.

From the results obtained, it is evident that:

1. Increasing the size of the plat to at least one twentieth of an acre, and probably much beyond, reduces variation.

2. The shape of the plat has an important effect on variation that has in the past been overlooked or misunderstood. More accurate results are obtained from single plats that are long and narrow and extend in the direction of greatest variation than from those of other shapes. Square plats or approximately square plats are to be preferred to long narrow plats that have their greatest dimensions in the direction of least variation.

3. The results from single plats are usually not sufficiently accurate to determine small differences between varieties or between fertilizer and cultural treatments.

4. The use of a unit of comparison composed of systematically distributed parts gives results that are much less variable than those obtained from an equal area in a single plat.

5. An increase in the number of replications of a plat of given size increases the accuracy of the results.

6. When the number of replications remains constant but the size of the plat replicated is increased, variation is reduced.

7. The most effective replicated block from the point of view of shape is one that is long and narrow and has its greatest dimension in the direction of greatest variation.

THE USE OF A SELECTION COEFFICIENT.[1]

C. H. MYERS.

INTRODUCTION.

In connection with the conduct of some corn-breeding work,[2] the writer has found a "selection coefficient" to be of considerable use in helping to make selections. A report of the use and application of this coefficient may perhaps be of service to others engaged in similar work.

PURPOSE OF THE SELECTION.

The selection was begun for the purpose of producing strains of dent corn better adapted to New York conditions. As the number of silos increased there was an increased demand for dent corns. Seed of these for the most part was obtained from the Central States, where the season is more suitable for corn growing. As a result of this practice, much of the dent corn produced in New York did not reach a sufficiently advanced stage of maturity, even for the best ensilage purposes.

The question of maturity was of prime importance. It was realized, however, that if maturity alone was considered it could be attained, of course, but probably at the expense of yield, which was also important. It was desirable to consider both of these qualities in conducting the selection work.

METHOD OF DETERMINING THE COEFFICIENT.

An adaptation of the individual ear-to-row method was followed. It is not the purpose here to describe the details, further than to say that 100 ears were chosen for the beginning and that each year of the experiment each ear in the plat was replicated at least once. The plat furnishing the material for the basis of this report was located in Saratoga Co., N. Y.[3] The elevation at this place is 400 feet. The

[1] Paper No. 80, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Received for publication January 10, 1920.

[2] This work was begun by Dr. H. J. Webber in 1908 and conducted by him until 1912. Since that time it has been in charge of the writer. Credit is due to Dr. H. H. Love for first suggesting the use of this coefficient.

[3] This work was done in cooperation with Mr. G. R. Schauber, Ballston Lake, N. Y., to whom much credit is due for the successful conduct of the experiment.

growing season has an average length of 154 days, with the average date of the last spring frost falling on May 6 and the average date of the first fall frost falling on October 7.[4] Only the early flint corns could be matured here in normal seasons. This location was, therefore, an excellent one for a corn plat planned for the purpose outlined above.

The yielding capacity of the different rows was determined at harvest time by weighing the corn produced in each one. These weights were recorded as "total yield per row." Another index of the yielding capacity was obtained by dividing the total weight of corn in each row by the total number of eared stalks in that row. This gave the "average yield per stalk." This latter method is possibly a more accurate measure than the former, especially in cases where the stand is not perfect. It is recognized that the latter is not an absolute measure, for the yield per stalk is very likely to be heavier in case of a thin stand. In the experiment under consideration, however, only ears of good germination were used as seed and the planting was made at a thicker rate than desired, the plants being thinned later to the proper stand. This method resulted in rather a uniform stand, altho there was always some slight variation in the number of stalks per row.

The maturity of each individual row was determined as follows: All the ears were sorted into two lots, ripe and unripe. The two lots of ears were then counted and the number of ripe ears was divided by the total number of ears, to give the expression which is called "percentage of maturity." This method of sorting into ripe and unripe is more or less an arbitrary one and is not absolute. On the average, however, if the work is done carefully, it results in a definite enough measure of maturity.

Having determined the yield and the maturity, it was desirable to combine both of these expressions into a single one which should serve as a basis for selection. This was done by multiplying the average yield per stalk by the percentage of maturity. This gave the "selection coefficient" which was used. Using the total yield per row instead of the average yield per stalk gave another coefficient. This was not markedly different from the first, which was the one adopted. Table I shows a portion of the data obtained from the Saratoga County plat in 1909. This table illustrates not only the method of obtaining the coefficients but also the amount of indi-

[4] Wilson, Wilfred M. Frosts in New York. N. Y. (Cornell Univ.) Agr. Expt. Sta. Bul. 316. 1912.

TABLE 1.—*Data from the first 50 rows, Saratoga County plat, crop of 1909, from which the selection coefficients were obtained.*

Row No.	Progeny No.	Number of stalks.	Number of suckers.	Total yield.	Yield per stalk.	Number ripe.	Number unripe.	Percentage of maturity.	Selection coefficient (total yield × percentage maturity).	Selection coefficient (yield per stalk × percentage maturity).
				Lbs.	*Lbs.*			*Pct.*	*Pct.*	
1	3-9-1	73	3	50.5	0.692	19	53	26.4	13.33	0.183
2	3-15-1	56	16	42.5	.759	19	30	38.8	16.49	.294
3	3-21-1	74	2	48.0	.649	30	40	42.9	20.59	.278
4	3-22-1	71	3	51.5	.725	18	47	27.7	14.27	.201
5	3-27-2	75	3	44.0	.586	21	44	32.3	14.21	.189
6	3-31-1	74	5	53.5	.723	11	60	15.5	8.29	.112
7	3-32-1	75	2	51.0	.680	19	52	26.8	13.67	.182
8	3-33-1	73	3	43.5	.596	24	40	37.5	16.31	.223
9	3-34-1	71	3	50.0	.704	13	57	18.6	9.30	.131
10	3-35-1	74	2	47.0	.635	23	43	34.9	16.40	.222
11	3-37-1	72	2	44.0	.611	17	51	25.0	11.00	.153
12	3-40-1	74	2	48.0	.649	25	43	36.8	17.66	.239
13	3-42-2	75	3	45.0	.600	13	53	19.7	8.87	.118
14	3-43-1	72	6	47.0	.653	37	30	55.3	25.99	.361
15	3-46-1	71	2	39.5	.556	14	36	28.0	11.06	.156
16	3-47-1	69	5	52.0	.754	20	50	28.6	14.87	.216
17	3-49-1	73	5	51.0	.699	18	50	26.5	13.52	.185
18	3-64-1	75	3	42.5	.567	21	42	33.3	14.15	.189
19	3-61-1	72	4	50.0	.694	27	40	40.3	20.15	.280
20	3-60-1	72	4	39.5	.549	27	30	47.4	18.72	.260
21	3-50-1	68	8	46.0	.676	4	55	6.8	3.12	.046
22	3-67-1	73	2	36.0	.493	13	36	26.5	9.54	.131
23	3-75-3	70	4	41.5	.593	16	41	28.1	11.66	.167
24	3-80-1	74	7	45.5	.615	29	34	46.0	20.93	.283
25	3-90-1	75	0	46.0	.613	23	46	33.4	15.36	.205
26	3-94-2	70	2	42.5	.607	24	38	38.8	16.49	.236
27	3-95-1	70	4	49.0	.700	7	59	1.1	.52	.008
28	3-9-2	72	9	50.5	.701	29	37	43.9	22.17	.308
29	3-21-2	72	5	44.5	.618	19	46	29.2	12.99	.180
30	3-22-2	68	8	47.5	.699	42	26	61.8	29.36	.432
31	3-27-3	66	4	44.0	.667	16	47	25.4	11.18	.169
32	3-31-2	74	5	52.5	.709	41	30	57.8	30.35	.410
33	3-32-2	73	9	51.5	.705	10	57	14.9	7.67	.105
34	3-33-2	62	4	39.5	.637	26	24	52.0	20.54	.331
35	3-34-2	72	2	48.5	.674	30	39	43.5	21.10	.293
36	3-35-2	73	3	49.0	.671	20	44	31.2	15.29	.209
37	3-37-2	70	6	43.5	.621	22	36	37.9	16.49	.235
38	3-40-2	69	6	46.0	.667	19	40	32.2	14.81	.215
39	3-41-1	72	5	47.5	.660	31	32	49.2	23.37	.325
40	3-42-4	68	8	46.5	.684	13	49	21.0	9.77	.144
41	3-43-2	73	5	51.0	.699	59	15	79.7	40.65	.557
42	3-46-2	73	6	48.5	.664	50	19	72.5	35.16	.481
43	3-47-2	73	5	44.5	.610	35	36	49.3	21.94	.301
44	3-49-2	75	4	41.5	.553	30	29	50.9	21.12	.281
45	3-50-2	73	4	46.0	.630	37	32	53.6	24.66	.338
46	3-60-2	75	5	49.5	.660	34	37	47.9	23.71	.316
47	3-61-2	72	10	49.5	.688	51	20	71.8	35.54	.494
48	3-64-2	71	5	49.5	.697	44	30	59.5	29.45	.415
49	3-67-2	74	5	49.0	.662	20	50	28.6	14.01	.189
50	3-90-3	73	4	35.5	.486	39	16	70.9	25.17	.345

vidual variation among the different rows with respect to both yield and maturity. For this year the yield of individual rows ranged from 30.5 pounds to 55.0 pounds, while the percentage of maturity ranged from 1.1 to 87.3. The value of the selection coefficient ranged from 0.8 to 62.2.

The rather close agreement between the two coefficients is shown graphically in figure 7. The solid line represents the coefficient obtained by using the total yield per row, while the broken line represents the one obtained by using the average yield per stalk. These two lines follow each other very closely.

USE OF COEFFICIENTS IN MAKING SELECTIONS.

At harvest time a number of ears from each progeny were reserved as seed ears. Wired tags were used for labeling. This procedure was followed because it was not feasible to make the calculations for the selection coefficient at the time of harvesting. It was easier to choose from six to ten seed ears from each progeny and reserve them, if necessary, until planting time, as this did not require much time or storage space. After the calculations described above were made, selections of the best rows for that year were made on the basis of the selection coefficient, the greater coefficients indicating the better rows from the standpoint of yield and maturity. The reserved seed ears from the unselected rows could then be discarded.

As stated above, each ear in the plat was always replicated at least once. It is interesting to compare the coefficient of selection for the same ear planted in different rows. It should be borne in mind that the arrangement of planting was such that these rows were not side by side but in different parts of the plat. A comparison of these two series of coefficients for the different years shows that they follow each other rather closely. That is, a row which has a high coefficient in one series has a correspondingly high one in the other series. This is illustrated graphically in figures 8 and 9, taken from data obtained in 1909 and 1910. The solid line in each case represents the coefficient for the first series, while the broken line represents it for the second series. The agreement here is not absolute, due partly at least to soil inequality, but in a general way they follow very closely, especially in the case of the extremes.

RESULTS OF THE SELECTION.

The remnants of the original seed ears with which the plat was started were saved and at different times during the course of the

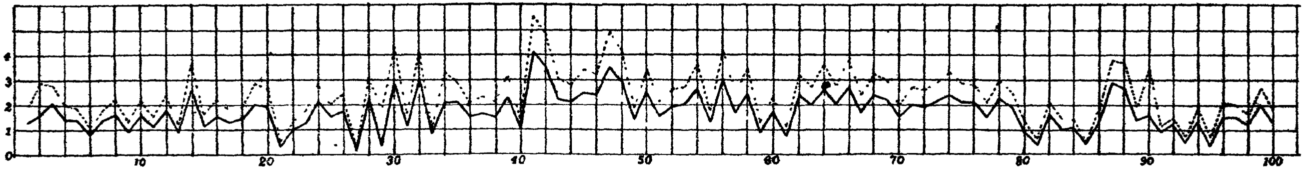

FIG. 7. Graph showing the relation between the two selection coefficients. (See page 109.)

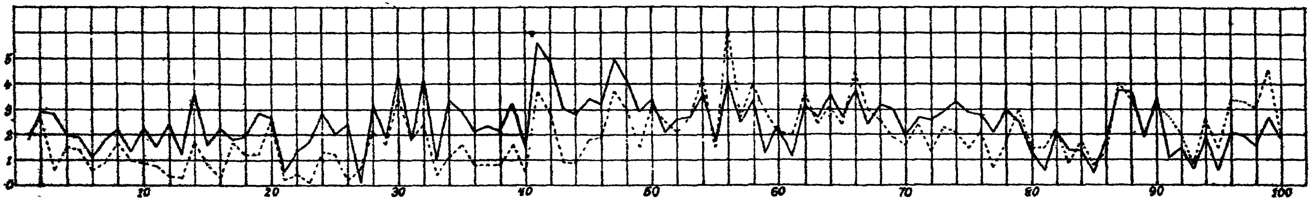

FIG. 8. Graph showing the relation of the selection coefficient for the same progeny planted in different rows, Saratoga Co. plat, 1909.

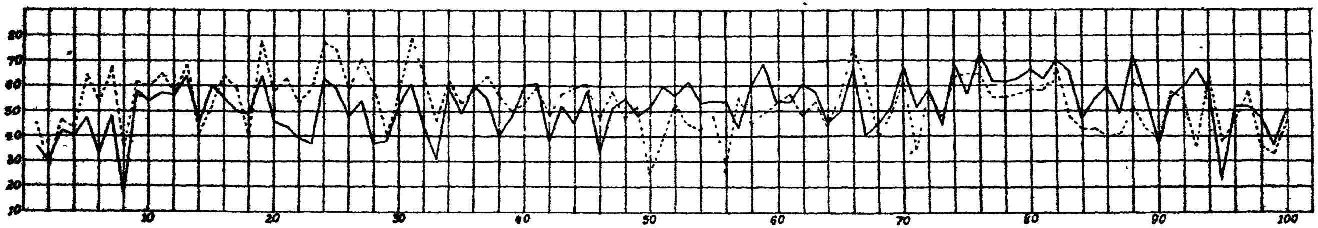

FIG. 9. Graph showing the relation of the selection coefficients for the same progeny planted in different rows, Saratoga Co. plat, 1910.

experiment served to furnish seed for a comparative test as to the progress of the selection. In each of these comparative tests, from five to ten rows 50 hills long, planted from a mixture of the original seed ears, were alternated with the same number of rows planted from a mixture of seed ears from the selected rows of that year. For convenience the former is labeled "original" and the latter "selected" in the table displaying these results.

Table 2 shows the results from the comparison plat in 1911, after three years of selection. The difference as shown by the yield per stalk is not striking, the average for the selected being 0.621 pound while that for the original is 0.650 pound. The average yield per stalk of the original is heavier than that of the selected, due to the immaturity of the former. When we compare the percentage of maturity, there is a striking difference, the average for the selected being 71.9 while that for the original is 13.2. In the last column of the table are given the selection coefficients for these rows, to illustrate the value of this in making selections from such material.

TABLE 2.—*Data from the comparison plat in Saratoga County in 1911 and 1912.*

DATA FROM 1911.

Row No.	Selected seed.[a]			Row No.	Original seed.[b]		
	Yield per stalk.	Percentage of maturity.	Selection coefficient.		Yield per stalk.	Percentage of maturity.	Selection coefficient.
11	0.673	66.7	0.449	12	0.643	21.6	0.139
13	.656	73.2	.480	14	.708	4.8	.034
15	.690	77.5	.535	16	.738	12.8	.094
17	.640	73.2	.468	18	.677	9.7	.066
19	.690	77.3	.533	20	.670	13.2	.088
11a	.649	65.2	.423	12a	.655	29.7	.194
13a	.560	71.4	.400	14a	.633	17.8	.113
15a	.490	69.2	.339	16a	.602	6.7	.040
17a	.565	67.5	.381	18a	.583	10.8	.063
19a	.600	77.5	.465	20a	.594	5.1	.030

DATA FROM 1912.

Row No.	Yield per stalk.	Percentage of maturity.	Selection coefficient.	Row No.	Yield per stalk.	Percentage of maturity.	Selection coefficient.
1	0.609	41.5	0.253	2	0.776	0	0
3	.554	56.7	.314	4	.800	0	0
5	.729	62.9	.458	6	.875	0	0
7	.650	63.8	.415	8	.740	0	0
9	.706	67.2	.474	10	.743	5.4	.040
Average..	.650	58.4	.383		.787	1.1	.008

[a] The selected seed consisted of remnants of ears selected from the 1910 crop for 1911 planting.

[b] The original seed was a mixture from the remnants of the original seed from Illinois.

In 1912 another such comparison plat was grown. The results from this plat are also summarized in Table 2. Again there is no striking difference between the selected and original with respect to the average yield per stalk. The latter has a somewhat heavier yield per stalk, but this again is due to its immature state. The percentage of maturity for both is greater in 1911 than in 1912, on account of an unusually early fall frost in the latter year. The percentage of maturity for the selected is 58.4 as compared with 1.1 for the original. Here again the selection coefficient has been calculated to illustrate its application.

The individual ear-to-row selection resulted in the isolation of five progenies of the original parent ears. Since 1913 no ear-to-row selections have been grown. Only mass selection from the standing corn in the field is now practiced. Varietal tests in which this strain is included indicate that it maintains its characteristc of early maturity combined with good yield.

BAHIA GRASS.[1]

JOHN M. SCOTT.

A large number of species of Paspalum are native to Florida. These are generally known as blanket grass or water grass, but sometimes as goose grass. In addition, several valuable species have been introduced from South America, including Dallis grass (*Paspalum dilatatum*), Vasey grass (*Paspalum larranyagai*), and lastly the species here discussed, *Paspalum notatum,* native in South America and northward to Mexico, for which the Bureau of Plant Industry suggests the name of Bahia grass. It gives most promise as a pasture grass. This was introduced into the United States in 1913 by the Bureau of Plant Industry under S. P. I. No. 35067.[2] Another introduction, S. P. I. No. 37996, was made in 1914.

Bahia grass was first planted at the Florida Agricultural Experiment Station in May, 1913. The original plat is still growing. From the very first this grass gave promise of being valuable.

On March 31, 1915, a plat of Bahia grass was planted in the pasture on the experiment station farm. The ground was plowed and a good seed bed prepared. Plants were taken from the original seed

[1] Contribution from the Florida Agricultural Experiment Station, Gainesville, Fla. Received for publication March 5, 1920.

[2] Accession number of the Office of Foreign Seed and Plant Introduction.

bed and set out in rows 24 inches wide, with the plants 24 inches apart in the row. Two rows, each about 200 feet long, were planted. The plat was fenced to keep off the stock. The grass made a good growth the first summer, and a good crop of seed was produced the first season. The latter part of September, 1915, the fence was removed and cattle have pastured on it both winter and summer since that time. During the past four years, the grass has been subjected to heavy pasturing. Notwithstanding this fact, it has continued to grow and has made a complete sod over a space now 10 to 12 feet wide. In addition to this, a large number of individual plants have sprung up adjacent to the planting, indicating that the seed has been scattered by the cattle, birds, or wind.

This is, we believe, a new method of testing the value of a grass for pasture. A grass to be of value for pasture should, in addition to being nutritious, have good staying qualities. That is, it must stand hard and close pasturing under all conditions. A grass that needs to be nursed and coaxed after it is once established is not desirable for pasture purposes.

The method here employed gives information on two important points, namely, the ability of the grass to spread and make a good sod while being pastured, and its palatability to cattle. The results of this test show that Bahia grass will spread and make a complete sod under pasture conditions. It has also shown that cattle like this grass, as they graze on it at all seasons of the year.

Bahia grass seems best adapted to a rather moist soil. This does not necessarily mean a low, poorly drained soil, but rather one that holds moisture well. However, it has been grown on rather dry, sandy soil on the experiment station grounds with fairly satisfactory results. It is not likely to be of any value when planted on dry, sandy ridges. Neither is it likely to be a success when grown on land that is subject to overflow, especially where the water stands for several days. The original seed plat and the plat in the pasture are both on land which is ordinarily considered first class farm soil in Florida.

Bahia grass is rather sensitive to cold. A temperature of 34 to 26 degrees will nearly always kill all green growth of this grass. The roots apparently are not injured by frost or light freezes. When moisture conditions are favorable, growth starts in the spring about the same time as other perennial grasses.

No commercial seed of this grass is yet available, but efforts are being made to establish a supply. It seeds freely in Florida when not pastured. When once established it should not be a difficult matter to gather the seed for additional planting.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

Thanks to the cooperation of certain members, the Society has shown a healthy growth during the past month. The membership reported in the February issue was 504. Since that time, 19 new members have been added and 2 lapsed members have been reinstated, while 1 member has resigned, making a net gain of 20 and a total membership at this date of 524. This is far less than it should be, however, and the further cooperation of the members in bringing the Society to the attention of agronomic workers is urged. The names and addresses of new and of reinstated members, the name of the member who has resigned, and such changes of address as have come to the attention of the officers, follow.

New Members.

Albertz, H. W., Agronomy Bldg., Univ. of Wis., Madison, Wis.
Bastian, Elias, Brookings, S. Dak.
Bonnett, O. T., County Agr. Agent, Blue Rapids, Kans.
Brown, B. A., Storrs, Conn.
Buie, T. S., Experiment, Ga.
Carter, C. E., Dept. of Field Crops, Agr. College, Columbia, Mo.
Corwin, Walling, Dept. of Field Crops, O. S. U., Columbus, Ohio.
Homewood, S. L., State College, West Raleigh, N. C.
Jensen, Ward C., Clemson College, S. C.
Landon, Ira K., 1511 Leavenworth Ave., Manhattan, Kans.
Leppan, H. D., Transvaal University College, Pretoria, S. Africa.
Letson, Orrin W., Dept. of Farm Crops, Agr. College, Columbia, Mo.
Lutz, Dexter N., Dept. of Farm Crops, O. S. U., Columbus, Ohio.
May, Ralph W., Judith Basin Substation, Moccasin, Mont.
Olinger, R. F., County Agr. Agent, Marion, Kans.
Suttle, A. D., College Station, Texas.
Tanner, E. L., College Station, Texas.
Vass, A. F., University of Wyoming, Laramie, Wyo.
Yost, T. F., 830 Fremont St., Manhattan, Kans.

Members Reinstated.

Hunnicutt, B. H., Lavras, Minas, Brazil.
Morgan, J. O., Experiment Station, College Station, Texas.

Member Resigned.

Wheeler, Clark S.

Changes of Address.

Cardon, P. V., Agr. Expt. Station, Bozeman, Mont.
Fahrnkopf, H. F. T., Farm Bureau, Bloomington, Ill.

GRANTHAM A. E., Va.-Car. Chemical Co., Richmond, Va.
KRAFT, J. H., College Station, Texas.
LE WORTHY, G. E., Harrington, Del.
PETRY, E. J., 1218 Catherine St., Ann Arbor, Mich.
WHITCOMB, W. O., Experiment Station, Bozeman, Mont.
WHITE, C. L., Aurora, Mo.

NOTES AND NEWS.

Jay A. Bonsteel, in charge of special soil studies in the Federal Bureau of Soils for the past several years, has resigned to engage in farming in New York.

John Buchanan, who has been in charge of cooperative experiments in agronomy at the Iowa station and secretary of the Iowa Crop Improvement Association since 1912, has resigned to become county agricultural agent in Story County, Iowa.

O. D. Center, formerly director of extension in Oregon, is now county agent in McLean Co., Ill., with headquarters at Bloomington.

C. C. Cunningham, in charge of cooperative experiments in agronomy at the Kansas station, has resigned effective March 1 to engage in farming.

W. H. Dalrymple, vice-director of the Louisiana station and head of the department of veterinary science in the Louisiana Agricultural College, has been made dean of the college of agriculture and director of the experiment station.

George E. Eggington, seed analyst at the Colorado station, has accepted a position with the Minneapolis office of Albert Dickinson Company, wholesale seed dealers.

F. E. Fuller, extension agronomist in the Montana college, has resigned to accept the position of agricultural adviser to the farm bureau of Marshall and Putnam counties, Illinois.

A. C. Hartenbower, superintendent of farmers' institutes and extension schools in Oklahoma, has resigned to engage in farming.

Harry Hayward, dean of the Delaware college of agriculture and director of the experiment station, has resigned to join the staff of N. W. Ayer & Son, a Philadelphia advertising agency. He has been succeeded by C. A. McCue, formerly horticulturist of the Delaware college and station.

David F. Houston, secretary of agriculture since March, 1913, on February 2 succeeded Carter Glass as secretary of the treasury. He was succeeded as secretary of agriculture by Edwin T. Meredith, of Des Moines, Iowa, owner of *Successful Farming,* a director of the Chicago Federal Reserve Bank, and president of the Associated Advertising Clubs of the World.

George Livingston, acting chief of the Federal Bureau of Markets since the resignation of Charles J. Brand last summer, has been made chief of the Bureau.

H. C. Ramsower, formerly professor of agricultural engineering in Ohio State University, is now director of extension in Ohio.

Albert Osenbrug, recently in charge of dry-land agriculture experiments at the Colby, Kans., substation, has been made superintendent of the Judith Basin Substation, Moccasin, Mont.

C. C. Ruth, formerly of the Portland, Oreg., office of grain standardization, Federal Bureau of Markets, is now assistant agronomist at the Oregon station, succeeding F. S. Wilkins, now of the Iowa station.

Herschel Scott, formerly assistant in agronomy at the Kansas college, resigned March 1 to engage in commercial work in California.

M. C. Sewell, assistant professor of soils in the Kansas college, is on leave for graduate study in the University of Chicago.

W. O. Whitcomb, recently in charge of the Minneapolis office of the seed-reporting service, Bureau of Markets, is now in charge of the seed laboratory of the Montana experiment station.

FLUCTUATION IN EXPERIMENTS REQUIRING PERSONAL JUDGMENT.

The variation in yield of potatoes shown in Table 5 indicates the great error to which experiments requiring the judgment of different people are subject. Potatoes were separated into piles considered marketable or unmarketable. The yields for the years preceding 1910 were much larger than in later years. This helps to reduce the individuality of the crop during the last years or to make them tend toward the larger yields. During the year 1906 when the production was over 100 percent above the average there seems to have been a serious error in classifying the potatoes in the unmarketable class for the 15-inch irrigation according to later standards or else there was an unaccountable proportion of marketable potatoes. Several years are required to smooth out a single large mistake in judgment. This great variation may account for the yields of the unmarketable potatoes during the last years being above the average, while the total and large potatoes are considerably below the average.

TABLE 5.—*Percentage variation from the average yield of total, marketable, and unmarketable potatoes without irrigation and with a seasonal irrigation of 15 inches of water.*

Year.	Unirrigated yield.			15-inch irrigation yield.		
	Total.	Marketable.	Unmarketable.	Total.	Marketable.	Unmarketable.
1902				28	47	−59
1903				44	42	18
1905	35	13	53			
1906	124	143	32	64	84	−45
1907	48	17	82	21	6	51
1908	35	50	−30	24	28	−18
1909	7	10	−24	43	53	−25
1910	− 32	− 55	3	−23	−45	46
1911	− 42	− 55	−26	−31	−46	7
1912	− 34	− 37	−44	−61	−78	− 6
1913	− 16	− 17	−34	−21	−33	10
1914	− 46	− 65	−11	−36	−54	19
1915	− 80			−52		
Average variation	45	46	34	37	47	28
Average yield (bu.)	124.16	91.96	42.15	182.04	150.56	40.12

FLUCTUATIONS IN DIFFERENT CROPS COMPARED.

The variation of several crops from their average unmanured 15-inch-irrigation yield is shown in Table 6 in order that comparisons of their relative stability during different years might be made. Disregarding the years when data were not available, the average variation is greatest for potatoes, followed in order by sugar beets, alfalfa, corn,

oats, and wheat. Yet the highest single variation was with oats in 1908, when it was 75 percent above its 14-year average yield. During several other individual years the variations of the crops were contrary to the averages. In general, however, the grains might be expected to give reliable results with fewer years than crops such as potatoes and beets which produce higher total yields per acre.

TABLE 6.—*Percentage variation from the average yield of wheat, oats, corn, alfalfa, sugar beets, and potatoes, irrigated at the rate of 15 inches of water a year.*

Year.	Variation from average yield of					
	Wheat.	Oats.	Corn.	Alfalfa.	Sugar beets	Potatoes.
1902	7	3	54		−54	32
1903	9	23	52	−21	−59	49
1904	16					
1905	13					
1906	28		11			70
1907	10					26
1908		75	− 9	−57		29
1909		10	−20	−19		48
1910	− 9	−23	−33	−18	18	−44
1911	− 7	− 9	− 7	28	30	−46
1912	28	18	11	30	20	−20
1913	−11	− 4	10	27	−19	− 3
1914	−20	− 4	−12	33	69	−33
1915	− 8	− 4	− 3	33	3	−46
1916	−19	−22	−24	−30	−29	−38
1917	−28	−22	−38	0	− 1	− 7
1918	− 2	−20	38	14	20	−17
1919	− 9	−20	−30	−20	2	1
Average variation	14.0	18.4	23.5	25.4	27.0	31.8
Average yield	41.95 bu.	67.62 bu.	71.59 bu.	4.23 T.	6.59 T.	175.85 bu.

PROGRESSIVE AVERAGE RESULTS.

It has become almost a universal practice to consider only the average results of experiments even when there are only two or three years' data. It is thought that a study of averages for each year of a few experiments will prove instructive in showing how completely one may be mistaken by promiscuously making close comparisons with data covering only a short period.

Unstability of First Years.—The average yields of grain and straw at the end of each year in tests with wheat at the Nephi, Utah, Experimental Dry-Farm are shown in Table 7. On land cropped two years in three, it was desired to find the difference in yield between land cropped the previous year and that previously fallow. During the first five years the yields were exceptionally low and only during

the years 1911 and 1912 did the yields of the crop following fallow exceed that of the continuously cropped plats. During the sixth year the yields were high but unaccountably in favor of the plats cropped the previous year. There was practically no difference in average yield of grain between the two plats at the end of the first 5 years. The average at the end of the sixth year, however, was over a bushel to the acre in favor of continuous cropping. From the sixth crop to the present, conclusions opposed to those of the sixth have rather decidedly held, nearly every year showing a greater relative difference. The abnormal years at the beginning of the experiment made it impossible during the first 7 years to arrive at what seems the correct relationship between these two cropping methods. The results are seen still to be erratic both in yield of grain and straw, indicating that close comparisons would not be warranted even at the end of 11 years.

TABLE 7.—*Progressive average yields of wheat and straw before and after a fallow year in an experiment with dry-land plats cropped to wheat two years in three, for the period 1909 to 1919.*

Year.	Progressive average yield of grain.		Progressive average yield of straw.	
	Before fallow.	After fallow.	Before fallow.	After fallow.
	Bushels.	*Bushels.*	*Pounds.*	*Pounds.*
1909	13.4	2.5	820	160
1910	11.9	5.4	825	355
1911	10.6	11.4	760	773
1912	8.9	10.2	635	703
1913	8.5	8.6	606	616
1914	14.4	13.8	1,060	933
1915	14.3	17.0	1,187	1,203
1916	13.5	17.1	1,117	1,184
1917	14.2	17.8	1,154	1,240
1918	13.7	17.6	1,007	1,207
1919	14.2	17.9	1,139	1,183

Progressive Shifting of Conclusions.—An experiment to discover the proper quantity of irrigation water to apply to corn manured at the rate of 5 tons to the acre each year has been run for 9 years. During the first year, as seen in Table 8, the yields were about proportional to the quantity of water added. The average of the first two years shows that the 10-inch irrigation became less effective than the 5-inch and the 40-inch less effective than the 30-inch and remained so thruout the experiment. The unreliable factor in this experiment is the relation the 40-inch and the 5-inch irrigations held to the other irrigation treatments as the test progressed. Comparisons made at the end of the fourth year would not have been true at the end of the fifth. The yields with 40 inches decreased from first rank in the be-

TABLE 8.—*Progressive average yield of ear corn without irrigation and with applications of 5, 10, 20, 30, and 40 inches each season from 1911 to 1919.*

Year.	Progressive average yield in bushels of ear corn irrigated at the rate of					
	0 inches.	5 inches.	10 inches.	20 inches.	30 inches.	40 inches.
1911 ...	52.7	62.5	69.2	77.8	82.8	87.6
1912 ...	70.3	77.8	74.3	80.1	88.2	86.4
1913 ...	78.1	86.8	86.5	89.5	92.0	91.8
1914 ...	76.3	89.1	83.4	88.1	91.3	90.1
1915 ...	72.8	85.4	82.8	88.4	91.0	85.3
1916 ...	73.3	86.2	83.0	87.7	90.4	83.8
1917 ...	75.0	87.4	85.9	88.5	91.6	84.6
1918 ...	76.7	91.4	87.8	91.1	93.1	85.5
1919 ...	73.5	87.7	83.9	88.7	89.9	82.8

ginning to last of the irrigations during the final three years and the 5-inch-irrigation yields tended to improve in comparison with the others. Considering the shifting positions of the averages during the eighth and ninth years, the variations in yield as indicated by the averages are still so great that dependable deductions on the relative value of the different irrigations can hardly be made.

LENGTH OF EXPERIMENT AND EXCEPTIONAL YEARS.

The percentage of sucrose in sugar beets irrigated at three different rates, together with their progressive averages, are given in Table 9

TABLE 9.—*Yearly percentage of sucrose and progressive average percentage of sucrose in sugar beets irrigated at the rate of 10, 15, and 20 inches of water each season from 1907 to 1919.*

Year.	Yearly percentage of sucrose.			Progressive average percentage of sucrose.		
	10 inches.	15 inches.	20 inches.	10 inches.	15 inches.	20 inches.
1907 ...	17.23	15.86	16.08	17.23	15.86	16.08
1908 ...	13.90	13.39	14.97	15.57	14.63	15.53
1909 ...	10.26	11.57	11.84	13.80	13.61	14.30
1910 ...	16.40	16.35	15.98	14.45	14.29	14.72
1911 ...	15.80	15.40	14.88	14.72	14.51	14.75
1912 ...	17.04	18.41	21.18	15.11	15.16	15.82
1913 ...	14.55	15.02	15.04	15.03	15.14	15.71
1914 ...	14.64	14.65	15.60	14.98	15.08	15.70
1915 ...	14.52	15.41	12.76	14.93	15.12	15.37
1916 ...	11.87	12.66	14.40	14.62	14.87	15.27
1917 ...	15.42	16.43	15.91	14.69	15.01	15.33
1918 ...	13.69	15.09	16.43	14.61	15.02	15.42
1919 ...	8.59	11.31		14.15	14.73	

to indicate the possible fluctuations of averages covering several years when an unusual season is encountered. The seasons of 1912 and 1916 throw the averages out of proportion to what would be expected

in the more normal years. The 20-inch irrigation took an abnormally high position in 1912 and remained noticeably high for the next two or three years, when a counteracting low percentage brought it down. It was following this 1912 abnormal year that the percentage of sucrose for the 10-inch irrigation fell below that of the 15-inch irrigation and remained there. During the tenth season, 1916, a subnormal percentage of sucrose occurred. The 15-inch irrigation treatment was affected proportionately more than the other two, throwing the treatment out of the relative position in which it apparently belongs. Being an average of 4 plats this relative shifting of positions is not thought to be caused by experimental error so much as to peculiarity of the season.

SUMMARY.

This paper includes data from experiments with potatoes, sugar beets, alfalfa, corn, oats, and wheat.

Short-time experiments are especially subject to error where a complete cycle of seasonal fluctuations is not included.

All treatments in an experiment are not affected relatively the same each season; the amount of divergence varies in different years.

Where variations from the average condition are large, a greater number of years are required for accurate conclusions than where the variations are small.

Manuring experiments show wider variations from the average than irrigation experiments.

Under dry-farming conditions variations are wider than under irrigation conditions and small irrigations vary more than where the plant does not suffer for water.

In these experiments potatoes varied in yield most, followed in order by sugar beets, alfalfa, corn, oats, and wheat.

Experiments requiring personal judgment vary more than where measurements are mechanical.

Average results during several abnormal years ran contrary to results in normal years that followed.

Progressive seasonal averages showed a gradual shifting of the relative positions of part of the treatments in an irrigation experiment with corn.

In experiments where variations are comparatively large, an exceptional season may seriously affect the average of a 10-year period.

THE COEFFICIENT OF YIELD.[1]

FRANK A. SPRAGG.

Heredity and environment stand side by side in the production of individual plants and animals. An individual with the best inheritance will fail under some environments, but the individual with poor inheritance is not capable of good production even in the best surroundings. The problem in interpreting experimental results is not how to eliminate environmental influences, but how to compare varieties on a uniform basis.

It is unnecessary to outline the development of the use of checks in varietal and other experiments, as its growth was simultaneous at most of the important experiment stations. By 1900, the check idea was fairly well understood and generally used, but even after nineteen years, agronomists differ as widely in their use of checks as the soils vary in the different sections. Some depend entirely upon the average of the results obtained from a large number of small plats. This replication idea is a good one, and may give fair results on uniform soil, but the check idea is also a good one, and must not be overlooked.

The method employed at the Michigan station makes use of both of these principles, incorporating replication and checks into one system. The old addition and subtraction method has been done away with, and a ratio (percentage) method put in its place. The results of the interpretations are called coefficients of yield.

The coefficient of yield is the quotient obtained by dividing the yield of a variety by the calculated yield of the standard or check variety, growing on the same plat the same year. This is a ratio that becomes unity when the yield of the variety it represents equals that of the standard. It is greater or less than unity when the yield of the variety it represents is greater or less than the yield of the standard.

This method of calculating results was adopted after other methods had failed to meet our conditions. For example, in the early days of varietal testing in Michigan, the contrast between the many poor

[1] Contribution from the Michigan Agricultural Experiment Station, East Lansing, Mich. Presented at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 13, 1919.

varieties and the few good ones was so great that even crude methods obtained results. The plats were often a rod wide and usually not over 8 rods long. Few checks were used and the soil varied so between them that large experimental errors were created in interpreting results. The addition and subtraction method of eliminating environmental influences was also used. Trouble came when dealing with such a problem as alfalfa seed production, where some lots produce almost no seed under good environment. The corrected results would often appear to be less than zero. The absurdity of the results proved that the addition and subtraction method was false.

We have improved the old methods in two ways, first, by making the checks more frequent, and second, by making the plat determinations more reliable thru the use of the principle of replication. With this arrangement, we feel warranted in assuming that the soil varies continuously between checks. This enables the calculation of the comparative yielding power of the check upon each and every plat in the series. In making use of the principle of replication it was early found that the replicated plats could be sown end to end, and that the many soil types would thus be sampled. Each collective replication is harvested as a unit. A large amount of expensive labor is saved and the reliability of the results is increased, because ten years of experience in handling small plats convinces the writer that when a number of small lots are harvested and thrashed separately a small loss for each lot creates a big mistake. The larger lot can be more easily kept from being mixed, allowing the use of the varietal series as increases of new pedigreed sorts, to be further increased if desirable.[2]

As a result, the varietal plat is a long and narrow strip, sampling as many soil types as possible and yet close enough to its neighbor to have approximately the same yielding power. The checks would not be possible by any other arrangement of the replication. Experience teaches that the distance between checks should not be more than one-twentieth of the length of the plats. It is better in some cases if this relationship can be less. Two and not to exceed four varieties are planted between each pair of checks. The number depends upon the shape of the tract available for test work and the amount of avail-

[2] The breeding work at the Michigan station has produced a number of new commercial varieties. The Alexander and Worthy oats were distributed in 1911. College Success, College Wonder, and Wolverine oats have been produced since that time. Several varieties of wheat have been distributed, of which the American Banner and Red Rock are the most noteworthy. The Red Rock wheat and Rosen rye have spread from the Atlantic to the Pacific.

able seed of each variety. Whenever possible, the varietal series is duplicated for the same reason a chemist duplicates his work.

The standard or check variety is as pure and as high-yielding a variety as the station possessed at the time of its selection. The same standard is maintained from year to year to test the variability of seasons as well as variations between different parts of the same field. It is best if the yield of the standard can be obtained yearly from a general field rather than to depend upon the yield of the standard in the series, where frequent alleys exist. The crop draws from the alleys. However, as the plats are all the same size and shape, the results are comparable and their relationship is reliable.

In 1913, when our department obtained a calculating machine, much time was spent investigating ways and means of getting more accurate results. These investigations led to the discovery that is here called the coefficient of yield. It has been tested in all kinds of connections during the past six years and found superior to any of the old methods of interpreting results.

The coefficient of yield has proved valuable to the crops work at the Michigan station and should likewise be found valuable to other investigators. In practice, it has been found best to express this ratio to the nearest fourth decimal place or unity plus four places when the coefficient is greater than unity. The expert statistician would say that this is more accurate than the facts justify. The answer is that these are figures in process and not the final results. The desire is that this relation will fully represent the numbers involved, so that the end results will be as accurate as the data. When we come to end results, expressed in bushels per acre, they will be given in bushels and tenths only.

In the case of a series of varieties that are tested thruout a series of years, the coefficients of yield that represent these varieties are found to be more reliable values, when comparing the yielding power of the varieties in question, than those given in bushels for a series of varieties that have been run different numbers of years. Dr. T. L. Lyon[8] mentioned this difficulty when considering sources of error in field tests. The main trouble is that a series of values in bushels per acre is a weighted series. The yielding power of the standard variety varies from year to year, depending upon varying climatic conditions. The corrected values (bushels per acre) that the experimenter obtained for a year's results are based on the yield of the

[8] Lyon, T. L. Some experiments to estimate errors in field plat tests. *In* Proc. Amer. Soc. Agron., 3 (1911), p. 113. 1912.

standard variety for that year. The results of another year are based on the yield of the same standard, but nevertheless on a different value, and thus each yield for a certain variety under test receives a different weight, and the average of such a series is a weighted average.

To overcome this difficulty in data that already have been calculated in bushels per acre, the experimenter must divide the corrected yields in bushels for a series of a certain year by the average yield of the standard in bushels for the same year. He would thus obtain the coefficients of yield for those varieties that year, provided he has used the ratio method of correcting results. Let him do this for each year and then average the coefficients of yield representing a variety during the period of years of the test. He would now have removed the weights and obtained an unweighted or normal average for that variety and likewise for each variety of the series. When a series of average coefficients of yield have thus been obtained, it is usually desirable to transform these into bushels per acre for the purpose of publication. This is done by multiplying each average ratio (coefficient of yield) by the average yield of the standard thruout the years. The experienced experimenter knows that environmental influences are heavy weights. Perhaps he may use the average of a lot of tests on the standard variety over the State to calculate his figure representing the average yield of the standard. If he sees best he can do this, to obtain figures for the other varieties based on greater adaptability. The flexibility of the method, using coefficients of yield, allows this to be done.

The preceding discussion refers to the handling of old data that have already been calculated in bushels per acre. Coefficients of yield can be more easily obtained from the original data. The yields in pounds per plat are placed in a column, which is usually marked P (plat yield). The next column contains the check yields (C). The third column gives the corresponding P/C. In the case of a check the value P for that plat is also the C and P/C equals unity. The other Cs are obtained by interpolation between checks. These results can be obtained graphically by placing the data on cross-section paper and drawing straight lines between the dots representing the yields of adjacent checks. This generates a broken line across the series known as the "normal." The points in which the normal intersects the plat lines are the values for C referred to above. The reliability of these values is indicated by the nature of the normal. It should not be an abrupt zigzag. The quotient P/C is the coeffi-

cient of yield calculated for each plat and can be placed in a third column.

The ratio method, upon which the coefficient of yield is based, considers the environmental influences as weights that it undertakes to remove, by eliminating the ratio between the yielding power of a plat and the yielding power of an average plat in terms of a standard variety. This ratio of yielding power is the weight that is removed when we take the quotient of the yield of a plat divided by the calculated yield of the standard variety on the same plat. This quotient is the coefficient of yield. 100 P/C is the same thing in percentage form. PK/C is the corresponding result in bushels or tons per acre, when K is the acre yield of the standard or check variety.

TABLE 1.—*Data obtained from the 1914 bean variety series at the Michigan station.*

Register No.	Strain.	Variety.	Yield of plat, pounds.	Yield of check, pounds.	Coefficient of yield	Calculated yield, bushels per acre.
40000..	81302	Robust	117.5	117.5	1.0000	34.19
40100	36	Shoesmith	71.0	123.7	.5740	19.62
40200..	40	Boston	69.0	129.9	.5312	18.16
40300	41	Unknown	78.0	136.1	.5731	19.59
40400.	42	Cook	90.0	142.3	.6325	21.63
40500.	81302	Robust	148.5	148.5	1 0000	34.19
40600	44	Landis, untreated	72.0	150.0	.4800	16.41
40700.	44	Landis, inoculated	68.0	151.5	.4488	15.34
40800..	44	Landis + 1 : 300 formaldehyde	67.0	153.0	.4379	14.97
40900	44	Landis + 1 : 500 $HgCl_2$	71.5	154.5	.4628	15.82
41000 .	81302	Robust	156.0	156.0	1.0000	34.19
41100	45	Scully	72.5	154.6	.4690	16.04
41200..	46	Geismar	39.5	153.2	.2578	8.81
41300	2	Red Kidney	50.5	151.8	.3327	11.38
41400	4	White Kidney	57.0	150.4	.3790	12.96
41500	81302	Robust	149.0	149.0	1.0000	34.19
41600..	81901	Selection from Commercial	79.0	145.0	.5448	18.63
41700	82103	Selection from Commercial	73.5	141.0	.5213	17.83
41800.	84204	Selection from Commercial	61.5	137.0	.4589	15.69
41900 .		Early Buff cowpea	17.0	133.0	.1278	4.37
42000 .	81302	Robust	129.0	129.0	1.0000	34.19

The 1914 bean varietal series may be taken as an example. There were two rows to each plat, which were thrown together by the puller. The plats were 637 feet long, with 28 inches between the rows. The two rows make the plats 4.67 feet wide. The Robust variety was used as a check. Four varieties were planted between checks. Five times 4.67 equals 23.35 feet. In this case the length of the plats is 27.3 times the distance between checks. Thus we feel warranted in assuming that the soil varies continuously between checks, enabling

the calculation of the check yield (C) for every plat of the series. There is an extra plat planted for edge outside the last check and next to the road.

Table 1 shows the results of the same series, the calculation of the Cs, P/Cs, and yields in bushels per acre. In this case the average yield of the checks was 140 pounds. The area of a plat was 0.06824 acre. This gives the average yield for the Robust bean of 34.19 bushels per acre. This is the K in the calculations. Multiplying each P/C by 34.19 gives the corrected yield of the other varieties of the series.

Thus far we have discussed only the simple coefficient of yield. Coefficients can be used to compare varieties from the standpoint of several qualities upon which the plant breeder wishes to base his selections. In wheat, yield and quality go hand in hand, and to these hardiness and stiffness of straw must be added, when they are determining factors. Quality can be expressed as a coefficient of yield by baking a loaf of standard each time a baking test is made. In this case the volume of the loaf for a certain variety will be represented by P. The corresponding volume for the check variety at the same baking is represented by C. Then P/C becomes the coefficient of loaf volume. A series of coefficients of yield and quality may thus be determined for a wheat series. If each pair of coefficients are now multiplied[4] together, a series of compound coefficients is determined. The variety having the highest compound coefficient will possess the best combination of yield and quality. Coefficients of hardiness and stiffness of straw may be separately determined, but we usually find they are already determined in the coefficient of yield, because they are factors directly affecting the yield and do not need to be determined further.

In the alfalfa breeding work, three considerations are of prime importance. These are hardiness, average yield of hay, and average yield of seed. The seed is a means to an end. The end is hay, but the variety is of little value to Michigan farmers unless it will endure severe winter conditions. The success of alfalfa as a hay crop in Michigan depends upon the success of a Michigan seed industry.

In the alfalfa breeding work, where individual records are kept with all the plants and the progeny rows include checks, coefficients

[4] One may think that these coefficients should be averaged. The fact that they should be multiplied together is seen, if we suppose a series that are equal to the standard in yield, $P/C = 1$ for yield. The varieties should then be compared directly as the quality coefficients. $1 \times P/C$ does not change it, but half of $1 + P/C$ reduces the variability of the series.

may easily be determined for hardiness, yield of hay, and yield of seed. These three coefficients multiplied together for each variety or progeny of the series will give the composite value in one figure. This product will be unity for each of the checks. A progeny giving a compound coefficient greater than unity may be considered superior to the check, three things being considered. The variety suited to Michigan conditions cannot be obtained unless the seed is produced in paying quantities. Thus it is necessary to include the hardiest high seed yielders as well as those that are best when hay production is also considered. Representative strains selected on these two bases are included when each new generation of alfalfa nurseries is set out.

An experimenter can compare varieties on the basis of their coefficients, simple or compound, much more easily than by means of their yields and qualities measured by any other units. In the case of the check, the coefficients are unity, and unity can be raised to any power and still be unity. It is very easy for the eye to separate the values that are less than unity from those that are greater than unity. All investigators will agree that the prime object in making yield and quality tests is to find the superior varieties, discard the inferior ones, and increase the best ones for the benefit of the public. Any method that will bring out the truth most forcefully is the one to be used.

THE HISTORY OF THE SILO.[1]

LYMAN CARRIER.

The term "silo" is of ancient origin and means a grain pit (2).[2] Hermetically sealed granaries either above or below ground, usually partly below and partly above, were in use in the dry Mediterranean countries long before the Christian era. Varro (4) states:

> Some farmers have their granaries under ground like caverns, which they call silos as in Cappadocia and Thrace while hither in Spain in the vicinity of Carthage and at Osca pits are used for this purpose the bottoms of which are covered with straw; and they take care that neither moisture nor air has access to them except when they are opened for use, a wise precaution because where the air does not move the weevil will not hatch. Corn stored in this way is preserved for fifty years and millet indeed for more than a century.

The Egyptians built batteries of granaries separate from their other buildings. These were constructed of masonry above ground, were conical in shape, and were filled through an opening near the top (5). The grain was taken out through a door near the base. They were used to store grain in years of plenty for years of scarcity. The accumulation of carbon dioxid from partial fermentation of the grain effectually preserved the remainder. Varro (4, p. 172) says:

> Those who store their grain in the pits which are called silos should not attempt to bring out the grain for some time after the silo has been opened because there is danger of suffocation in entering a recently opened silo.

Attempts to introduce this method of storing grain into France early in the nineteenth century copied from underground silos used in Spain failed because of the porous nature of the soil and seepage of water. This trouble was finally overcome by Doyere in 1855, who suggested building masonry silos lined with sheet iron. The Paris Omnibus Company constructed several silos, some underground and some above, after Doyere's plan which were in use for several years (5).

The practice of storing grain in underground pits was not confined to any one country or race of people. Some tribes of American In-

[1] Contribution from Office of Forage-Crop Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication February 27, 1920.

[2] Numbers in parentheses refer to "Literature cited," p. 181.

dians made use of this method to store their own corn while they were away on winter hunting expeditions (14). It was practiced more or less perhaps by all nomadic peoples.

There does not appear to be much connection, however, between this ancient method of storing grain and modern methods of ensiling forage. About all that the old method furnished was the name "silo" for the structure for the new process, from which were derived the terms silage and ensiling. As the secret of success of storing grain in silos was to have it dry when ensiled it does not seem probable that the preserving of green forage by the same method would be the natural outcome.

ENSILING GREEN FORAGE.

It is impossible to say when or where the practice of preserving green forage in pits or silos originated. The statement has been made many times that the process was known and practiced by the Romans. Not much evidence is apparent to substantiate this statement. Cato (4, p. 43) does say:

> As long as they are available feed green leaves of elm, poplar, oak and fig to your cattle and sheep.
>
> Store leaves also to be fed to the sheep before they have withered.

As the first reference in modern times to the matter of storing green forage for cattle, that of Prof. John Symonds (11) of the University of Cambridge in 1786, was made from observations in Italy of the process of preserving the leaves of trees in casks and pits, it seems highly probable that the practice as far as that class of forage is concerned comes down from the time of the Romans. A French correspondent to The American Farmer (13) in 1875, referring to the preserving of green forage, states:

> There is nothing positively new in the idea. Since time immemorial vine leaves have been preserved in a green state in the district of Lyons and which has made the reputation of the famous Mt. Dore cheese.

If it had been customary for the Roman farmers to ensile green grains and other forages it seems probable that some of the agricultural writers of the time would have mentioned it. Their descriptions, however, with the exception noted above, deal with the storing of dry seeds in silos and not with green forages.

No matter whether the ancients ensiled green forages or not, the modern practice traces directly to the process of making sour hay in Germany and Hungary. This method was called to the attention of

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THE STATUS OF LIME IN SOIL IMPROVEMENT.[1]

ELMER O. FIPPIN.

The use of lime on the soil is shown by practical experience to be needed by such large areas and the scientific questions involved with its correct and economical use are revealed to be of such complicated and far-reaching character that the further investigation of this subject is a matter of major importance in crop production and soil improvement.

The underlying scientific reasons for this need for lime and the functions performed by it in the soil and in the plant are still matters of wide differences of opinion among investigators. This discussion ranges over the questions: Is there free acidity in the soil? What is the relation of free acid to the lime or other base-absorption coefficient of the soil? What tests, if any, constitute an adequate measure of the need for lime by a particular soil for the growth of so-called acid-sensitive crops? Is free acidity in itself the limiting factor or is it correlated with some other condition which is responsible for the character of plant growth, such as the presence of aluminum nitrate?

The opinion is quite general among investigators that the need for lime is associated either in a direct or an indirect way with an acid condition of the soil as measured by the absorption of a base, upon which principle rests most of the methods of measuring the need for lime.

THE USE OF LIME MATERIALS IN THE SOIL.

Concerning the range of tolerance by different crops of an acid condition of the soil, very little is definitely known, but a wide varia-

[1] Presented at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 10, 1919.

tion is indicated, for example, by the distinctions between alfalfa and blueberries or red sorrel and red clover. The sorrel plant (12, 14)[2] illustrates a further fact, namely, that some plants have a wide range of tolerance of both an acid and a lime-rich condition of soil, while other plants may have a narrow range of tolerance.

The range of tolerance of microscopic plants such as those concerned with the transformation of nitrogen and those concerned with the production of a diseased condition of plants, such as the potato scab (5) and the club root of cabbage, is equally important from the viewpoint of farm practice. The lack of accurate information concerning the tolerance of the lower plant forms is equally as great as it is concerning the higher plants. Certain it is that plants cannot be divided sharply into two classes, one of which will thrive only on an alkaline soil while the other will thrive only on an acid soil. We believe that every graduation of tolerance is exhibited among different plants. Herein arises another important point.

Too often it has been assumed that for plants that thrive on a soil near the neutral point too much lime carbonate could not be present in the soil. The question might very properly be asked whether the alkaline or calcium-magnesium tolerance of plants may not be quite as important to determine as their tolerance of the opposite or so-called acid condition.

The investigations of Fred[3] of Wisconsin, the studies of chlorosis (4) or inability to absorb iron in certain lime-rich soils in Florida, and field observations by the writer and others point to the importance of this subject.

EFFECTS OF LIME ON SOIL.

Coming now to the use of lime on the soil, including both the caustic and the carbonate forms, two classes of problems arise, namely, (*a*) What are the relative effects of equal amounts of the oxides of calcium and magnesium on the chemical, physical, and biological properties of the soil? and (*b*) What are the relative practical aspects of the use of these different materials?

Several investigations are in progress on the effect of liming materials on the chemical nature of the soil and the soil solution, under laboratory, plat, and field conditions. These have not reached a conclusive stage, as is illustrated by the data on the relation of lime to the availability of phosphorus and to a less extent of potassium (1, 3). Equally undetermined is the ultimate relation of lime to the

[2] Reference is to "Literature cited," p. 123.

[3] Personal communication to the writer.

store of nitrogen in the soil, especially when its use is combined with the growth of a legume.

Much misinformation has been given out on the effect of different forms of lime on the disappearance of organic matter from the soil. Here, distinction has not been made between purely chemical effects of the lime compound on the organic matter and the biological effects resulting from the stimulation of the growth of microorganisms in the soil by lime materials. The growth of such organisms is inevitably at the expense of the organic matter in the soil. To what extent is this effect necessary and legitimate and to what extent may it be undesirable? Is it a similar effect for both carbonate and caustic forms of lime?

The statement, common in the older agricultural literature (8), that caustic lime applied to the soil in even reasonable amounts is especially destructive of organic matter, has usually been put in a form to indicate that this destruction is a purely chemical process, such as occurs when spontaneous combustion of inflammable material results from the contact of a large amount of water with a considerable quantity of quick lime. This idea of the destruction of organic matter has extended to hydrated lime, because it also has caustic properties, but it has no capacity for chemical union with water involving the liberation of heat. Further, the slacking of lime in the soil, say as granular quick lime, cannot result in the rise of temperature necessary to a destructive chemical change. Unquestionably there is chemical union of the lime with constituents of the organic matter. That this union is truly destructive of the organic substance, as would be indicated by the liberation, even in strongly alkaline solutions, of carbon dioxide, has not been demonstrated and the phenomena are not in accord with the known principles of organic chemistry.

The chemical and biological relations of this problem must be kept clearly separated. If organic matter decomposes more rapidly where caustic forms of lime have been used than where carbonate forms have been applied, as is frequently claimed, it raises the question whether, as a result of these more active chemical and biological reactions, the use of caustic forms of lime in suitable amounts may be better than the use of carbonate forms. Who can say what are the relative effects of caustic and carbonate forms of lime on the granulation and on the porosity and related properties of different soils? Are these effects the same or do they vary with different kinds of soil? Available data indicate that in any direct way caustic

forms of lime have the largest granulating effect (2) on clay soils, while carbonate forms are either nearly inactive or produce positively an unfavorable physical change. Do the available data on this point furnish an adequate guide?

Closely connected here is the question of how long caustic lime remains in the hydrated form in the soil, and into what new combinations either the caustic or carbonate form enters in the soil. MacIntire (11) and Mooers of the Tennessee station have done much work showing, first, that caustic forms of lime are not chemically destructive of organic matter; second, that recarbonation proceeds very rapidly and is normally completed in a few days at the outside; and third, that magnesium and to a less degree high calcium limes rapidly enter in silicate combinations and that these new combinations markedly affect the solubility and movement of those constituents in the soil. Especially does the magnesium seem to increase the movement of sulfur. Conner[4] of Indiana has data showing that calcium in silicate combination, as in basic slag, may be nearly as effective in performing the functions of lime in the soil as when applied in caustic or carbonate form.

FORMS AND FINENESS.

This matter of the value of lime in certain types of silicate and similar combinations is particularly important because it is related to the matter of fineness of lime materials applied to the soil. If lime in these silicate forms of combination is just as effective in affecting the yield of crops as if it were in carbonate form, it is then quite as permissible to apply those forms of lime that enter most actively into these new combinations, namely, burnt lime and finely pulverized carbonate, as to use the more inactive coarse carbonate. There may even be an advantage from the formation of these silicates because, first, they suggest the precipitation of colloidal silicates; second, they maintain a more mild alkalinity; and third, they aid in conserving the lime materials in the soil without interfering with their usefulness.

Growing out of this same question of form and fineness is the question of the movement of lime thru the soil and the possibility of loss from leaching. The lysimeter data (10) collected at Cornell University during five years do not show any increase in loss of calcium and magnesium when lime was applied. These short-period data are vitiated by the existence of a large amount of limestone in the deep subsoil, which would tend to mask any movement from the surface

[4] Personal communication to the writer.

soil. MacIntire has found the leaching of lime thru a deep section of soil to be essentially independent of the rate of application in any ordinary period of a few years. Let it be noted here that we are not concerned with what may happen in a thousand years, but with what is the practical loss from the vertical soil section that will occur in three, five, or ten years, which is as long a period as the application of lime is intended to cover.

The analysis of the soil of one of the fields at Rothamsted (6) shows the presence of as much as 3.3 percent of carbonate of lime in the surface 9 inches and none in the second 9 inches. This carbonate of lime seems to be the result of application of chalk so long ago that the record is lost. Its persistence in the soil and the lack of movement into the subsoil indicate how slow is the movement of lime materials.

We come now to the question of suitable fineness of limestone. We have largely disposed of the question of extreme fineness. The next question here is, how large may particles of lime carbonate be and still perform the full functions of such material in the period for which it is applied, namely, from three to six years or for an average rotation? First of all, let us be reminded that certain processes in the soil are inhibited, as compared with their operation in a free liquid. This is especially true of diffusion. Lime carbonate is soluble in an acid solution, and will continue to dissolve as long as the acid is present in contact with the material. In the soil, the question arises, thru how wide an area of soil does diffusion operate when this soil is in the optimum moisture condition? From most of the investigations available it seems to be very slow, and to reach a very short distance from the point of solution. If there is more lime in a particle than is required to neutralize the acid solution or satisfy the lime-absorption coefficient of the soil within the active range of the surface of the lime particle, then at the end of this reaction the remainder of the particle of lime will be essentially sealed in a shell of the alkaline soil where it may remain for a long period except as it is disturbed by mechanical means. How coarse may a particle be before this condition occurs in the average acid soil? Is the maximum size of such a particle as large as one fourth or one tenth of an inch in diameter, or is it down around one fiftieth to one eightieth of an inch in diameter? The practical data on this point are very meager. Observations on calcareous glacial soils reveal particles of carbonate of lime in soils the greater part of which are distinctly acid to litmus and which respond with larger crop growth where lime is

applied. Experimental field data (7, 9, 13, 15) are available for so short a period or have been secured under such conditions of soil, crop succession, and rate of application as to make them of questionable value as a guide in this practical matter. Certain it is that such studies are not adequately conducted unless four conditions are met:

1. The soil must be distinctly in need of lime thruout a vertical section at least 4 feet deep from the surface.
2. The limestone must be sorted into rather narrow textual divisions and used in oxide-equivalent amounts.
3. The rates of application should range from a very small quantity, such as 200 or 300 pounds, up to as large a quantity as several tons.
4. The crop should be one sensitive to an acid condition and one not able to succeed in that soil without lime.

A fifth condition may be added, namely, insurance that there is an adequate supply of nutrients such as phosphorus. The question of suitable fineness cannot be regarded as settled in any sense, nor is it sufficient to advise the use of a large quantity of coarsely ground material on the chance that there may be enough fine material to supply the needs of the soil for good plant growth. This runs into economic questions. A further point involved is the extent to which the time element may compensate for lack of fineness.

FIELD EXPERIMENTS AT THE PRESENT TIME.

Almost none of the field experiments involving the study of lime materials is designed in a way adequately to investigate any one or more of the important scientific and practical problems involved in the use of liming materials on the soil. Certainly no adequate data of that sort have accumulated. This is not meant to cast any undue reflection on such carefully maintained or long continued work as that at the Ohio, Pennsylvania, and other stations. In the planning of those experiments the natural human limitation attaching to the investigations in a new field has been involved.

RELATION OF FORM OF LIME TO THE TYPE OF SOIL.

The questions of caustic *vs.* carbonate lime, fine *vs.* coarse lime, calcium *vs.* magnesium, and the amount of lime necessary for particular crops have not been settled by scientific investigations and for the guidance of practice must rest largely on the empirical results of field trials. Such empirical or practical field data as well as real experimental work should include results obtained on a number of

types of soil. It is not safe to draw conclusions from results on a single type of soil.

Finally, the practical aspects of these questions are embodied in laws covering the sale of liming materials, which are now widely divergent in procedure and requirements, and reflect the unsettled state of the general knowledge on the subject. Certainly, the essential elements of a lime-inspection law must be very much the same in the different States. If it is oxides of calcium and magnesium with which the farmer is concerned, then the first step would seem to be to report all forms of liming materials, both carbonate and caustic, on the basis of their oxide content. If fineness is a factor in value, then the fineness of carbonate materials should be reported for a standard series of screens ranging in size from the coarsest material that has appreciable value down to as fine materials as seems to be of importance under field conditions. The United States Bureau of Standards has recently promulgated a new system of specifications for testing screens, and all provision for screen analysis should be in harmony with these specifications and uniform among the different States.

I hope that the information, energy, and facilities of all the workers in the field of soil and crop improvement may be pooled in some kind of a broad conference to study all these questions, and as rapidly as possible to standardize our information and practices with reference to the use of lime in soil.

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THE INHERITANCE OF RESISTANCE TO BUNT OR STINKING SMUT OF WHEAT.[1]

E. F. GAINES.

The material presented in this paper concerns the bunt resistance of three wheats, Turkey (Washington No. 326), Hybrid 128 (Washington No. 592), and Florence (Washington No. 634), and the resistance of the F_2 and F_3 as well as selections in the F_4 generation of two crosses, Turkey × Hybrid 128 and Turkey × Florence.

The wheats under investigation at the Washington Agricultural Experiment Station show great variation in susceptibility to bunt (*Tilletia tritici*). The comparative resistance of thirteen different varieties under conditions of maximum infection is described in an earlier article.[2]

DESCRIPTION OF PARENTS.

According to the previous report, Turkey (*T. sativum vulgare*) produced 1.81 percent of bunt, whereas Hybrid 128 (*T. sativum compactum*) with similar conditions of infection produced 92.15 percent. These two varieties are of considerable importance in Washington, about 2,000,000 bushels of Hybrid 128 and 1,000,000 bushels of Tur-

[1] Contribution from the Washington Agricultural Experiment Station, Pullman, Wash. Received for publication February 9, 1920.

[2] Gaines, E. F. Comparative smut resistance of Washington wheats. *In* Jour. Amer. Soc. Agron., 10, no. 3, p. 218–222. 1918.

key being grown in 1918, which was approximately 40 percent of the winter wheat produced in the State that year.

Notwithstanding its great susceptibility to bunt, Hybrid 128 is so prolific, so winter hardy, has such stiff straw, and holds the grain so well after maturity that it is grown in larger quantities than any other winter wheat in Washington. The grain weighs well and grades commercially as white club. If it were not for its susceptibility to bunt, it would be grown by many farmers who now sow other varieties.

Turkey wheat is drouth resistant, winter hardy, of high milling quality, bunt resistant, and grades as hard red winter. It is produced in considerable quantities in the semiarid sections of Washington in years that are favorable for winter wheat. The straw is not so stiff as that of Hybrid 128, the grain shatters more easily, and the beards are objectionable.

Florence is a spring wheat of Australian origin, grading as common white, which has also proved to be highly resistant to bunt. It is not grown commercially in Washington.

RESISTANCE OF PARENTS AND HYBRIDS COMPARED.

In the summer of 1915, several hybrids were made between Turkey and Hybrid 128, and between Turkey and Florence. In 1918, a complete F_3 of each of these crosses was analyzed for bunt resistance. The parent varieties and F_2 sibs were grown in the same plat with the F_3 rows under the same conditions and in the same year, for more direct comparison. Turkey and Florence both showed a high degree of resistance, but Hybrid 128, altho very susceptible, did not smut so badly as indicated by the 4-year average of the same variety. The F_2 of Turkey × Hybrid 128 showed an infection intermediate between the two parents. The F_2 of Turkey × Florence produced a much higher degree of bunt than either parent. In this cross the lack of winter hardiness on the part of Florence made it difficult to get large numbers. Table 1 shows the actual numbers as they were counted in the field and is the basis of the percentages given in Table 2.

The data presented in Table 1 are all taken from field records. The material was grown on land that had been in peas the year before. Approximately a half gram of bunt spores was added to each packet of seed before sowing, in order to obtain maximum infection. The sowing was all done the same week and at a uniform depth. The soil was uniform and in good condition. The rows

were 18 inches apart and the seeds were spaced 6 inches apart in the row. During the spring and summer, enough cultivation was given to keep down weeds. At harvest time the plants of each row were pulled and divided into three classes, bunt-free plants, partly bunted plants, and entirely bunted plants. The number in each class was then recorded. The partly bunted plants were further divided into heads of wheat and heads of bunt, and the number of each recorded. In case a head was partly bunted it was placed with the pile it resembled most.

TABLE 1.—*Number of plants bunt free, partly bunted, and entirely bunted in 1918, with the number of uninfected and bunted heads produced by the partly bunted plants.*

Variety or hybrid.	Number of plants.				Number of heads on partly bunted plants.	
	Bunt free.	Partly bunted.	All bunted.	Total.	Not bunted.	Bunted.
Turkey	485	17	0	502	191	41
Hybrid 128	43	46	59	148	228	404
Florence	81	5	0	86	37	11
Turkey × Hybrid 128, F_2	45	93	53	191	678	613
Turkey × Florence, F_2	143	31	5	179	331	188
Turkey × Hybrid 128, F_3	3,678	4,094	3,814	11,586	27,194	26,223
Turkey × Florence, F_3	1,603	257	199	2,059	2,282	1,902

To get the percentage of infection, the number of partly bunted plants and those entirely bunted were added and the sum divided by the total number of plants in the row.

In figuring the percentage of bunted heads on the infected plants, it was assumed that the plants which were entirely bunted had the same average number of heads as the partly bunted plants, the number of the latter being determined by actual count. To get the total percentage of bunt produced, the percentage of totally bunted plants was added to the percentage of bunt produced by the partly bunted plants when figured in terms of the whole row.

The number of rows indicate the number of replications of the parent varieties and F_2 sibs, and show the size of each F_3 family. It is understood that each F_3 row is the product of an F_2 plant, grown in 1917. All the F_3 rows of each cross are the progeny of a single F_1 plant produced in 1916. The F_2 rows grown in 1918 were from 2-year-old seed of F_1 plants which were full sisters of the F_1 ancestors of the two F_3 families. The data are presented in Table 2.

Table 2 shows the high degree of resistance of the Turkey and Florence varieties. Hybrid 128 is less susceptible to bunt than usual, but all varieties showed an abnormally low percentage of the disease in 1918. Not only do Turkey and Florence show a much lower infection than Hybrid 128, but the infected plants themselves produce much less bunt than the infected plants of Hybrid 128. This is significant in itself, as it suggests the possibility that there are two kinds of resistance, one which prevents infection and one which retards the development of the fungus after infection.

TABLE 2.—*Percentage of infected plants, percentage of bunt on infected plants, and total percentage of loss from bunt in 1918 of the three parents and F_2 and F_3 generations of Turkey × Hybrid 128 and Turkey × Florence.*

Variety or hybrid.	Infected plants.	Bunted heads on infected plants.	Total bunt produced.	Number of rows.	Average number of heads per plant.
	Percent.	*Percent.*	*Percent.*		
Turkey	3.4	17.7	0.6	6	13.6
Hybrid 128	70.9	63.9	59.8	3	13.7
Florence	5.8	22.9	1.3	3	9.6
Turkey × Hybrid 128, F_2	76.4	47.9	51.0	3	13.9
Turkey × Florence, F_2	20.1	35.5	8.9	2	16.7
Turkey × Hybrid 128, F_3	68.3	49.1	50.2	194	13.0
Turkey × Florence, F_3	22.1	45.5	15.4	168	16.3

The F_2 of Turkey × Hybrid 128 shows a higher infection than the susceptible parent, but a much lower percentage of bunt is produced on the infected plants. The latter condition is to be expected as an intermediate condition, but it is difficult to explain the former except as a parallelism of increased hybrid vigor, which might cause more of the infected plants to survive the winter. The average of the F_3 bears out this supposition, for there is a slight reduction in the percentage of infected plants and a very slight increase in the percentage of bunt on the infected plants.

The F_2 of Turkey × Florence has a much higher degree of infection than either parent and also a higher percentage of bunt on the infected plants. The average of all F_3 rows shows a slight increase in the percentage of infected plants over the F_2 and a decided increase in the percentage of bunt on the infected plants. If resistance is caused by a series of chemical or physiological factors, then two facts are self evident. Most of the factors for resistance are recessive, and Turkey and Florence each have different and distinct factors for resistance.

AVERAGE RESISTANCE, IN F_3, OF DIFFERENT MORPHOLOGICAL SEGREGATES.

TABLE 3.—*Distribution of bunt infection among the different morphological types segregating in the F_3 of Hybrid 128 × Turkey.*

Spike characteristics	Number of rows.	Plants bunt free.	Plants all bunt.	Plants part bunt.			Total number of plants.
				Number.	Wheat heads.	Bunt heads.	
Long bearded	7	199	187	131	835	1,096	517
Long mixed	24	549	505	508	3,399	2,714	1,562
Long beardless	6	105	165	63	374	418	333
Mixed bearded	13	355	214	346	2,626	2,041	915
Mixed mixed	52	863	1,065	1,267	8,334	7,703	3,195
Mixed beardless	24	391	382	472	3,027	3,297	1,245
Club bearded	14	311	198	307	2,090	2,013	816
Club mixed	33	587	610	676	4,479	4,346	1,873
Club beardless	21	318	488	324	2,030	2,595	1,130
Total	194	3,678	3,814	4,094	27,194	26,223	11,586

In Table 3, the F_3 of Turkey × Hybrid 128 is arranged according to the characteristics of head length and floral-glume appendage. The distribution of the nine types is quite abnormal for a dihybrid. There are far too many rows homozygous for the club character and also for the beardless character. This is a common variation in certain crosses of this strain of Turkey, but it is outside the province of this paper to discuss this point.

TABLE 4.—*Distribution of bunt infection among the different morphological types in the F_3 of Hybrid 128 × Turkey, figured in percentages.*

Spike characteristics.	Number of rows.	Plants bunt free.	Plants all bunt.	Plants part bunt.	Bunt heads on partly bunted plants.	Total bunt.	Average plants per row
		Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	
Long bearded	7	38.49	30.17	25.34	56.75	50.55	73.9
Long mixed	24	35.15	32.33	32.52	44.40	46.76	65.1
Long beardless	6	31.53	49.55	18.90	52.78	59.52	55.5
Mixed bearded	13	38.80	23.38	37.80	43.73	39.90	70.4
Mixed mixed	52	27.00	33.30	39.65	48.03	52.34	61.4
Mixed beardless	24	31.40	30.68	37.90	52.13	50.43	51.9
Club bearded	14	38.10	24.30	37.62	49.06	43.26	58.3
Club mixed	33	31.34	32.57	37.00	49.24	50.79	56.8
Club beardless	21	28.14	43.18	28.67	56.11	59.27	53.8
Total	194	31.75	32.92	35.34	49.01	50.27	60.8

Table 4 presents the data of Table 3 in terms of percentages for comparison. There is a wide difference in the total percentage of bunt produced by the different types. The club beardless type is highest (59.27 percent) or almost identical in total bunt with the sus-

ceptible parent of the same type. The rows that had mixed long and club bearded heads produced the smallest amount of bunt (39.90 percent). The correlation of bunt resistance and morphological characters breaks down, however, when all bearded types are added together and compared with the sum of the beardless types and a similar comparison made between the sum of all long and all pure club types. The slightly higher resistance of the bearded types is well within the limits of error to be expected in an investigation of this kind.

TABLE 5.—*Distribution of bunt infection among the bearded, mixed, and beardless F_3 rows of Turkey × Florence, as shown by actual count of bunt free, all bunted, and partly bunted plants.*

Spike characteristics.	Number of rows.	Plants bunt free.	Plants all bunt.	Plants part bunt. Number.	Plants part bunt. Wheat heads.	Plants part bunt. Bunt heads.	Total number of plants.
Bearded......	38	387	74	90	823	585	551
Mixed	78	795	86	112	1,017	892	993
Beardless.....	52	421	39	55	442	425	515
Total.	168	1,603	199	257	2,282	1,902	2,059

The distribution of types in the F_3 of Turkey × Florence shows the same prepotency of the beardless type. The total number of plants, however, suggests greater winter hardiness of the bearded types.

TABLE 6.—*Distribution of bunt infection among bearded, mixed, and beardless F_3 rows of Turkey × Florence, in percentages.*

Spike characteristics.	Number of rows.	Plants bunt free.	Plants all bunt.	Plants part bunt.	Bunt heads on partly bunted plants.	Total bunt.	Number of plants per row.
		Percent.	Percent.	Percent.	Percent.	Percent.	
Bearded........	38	70.2	13.4	16.3	41.5	20.2	14.5
Mixed.........	78	80.1	8.7	11.3	46.7	14.0	12.7
Beardless........	52	81.7	7.6	10.7	49.0	12.8	9.9
Total.....	168	77.9	9.7	12.5	45.5	15.4	12.6

According to Table 6, there is an inverse correlation between the bearded characteristic and bunt resistance. In Table 2, Turkey was shown to be twice as resistant as Florence, yet in the F_3 the bearded rows produced nearly twice as much bunt as the beardless rows. In Table 4, the long bearded type produced almost 4 percent more bunt

than the long beardless type, which is a variation in the same direction. With the club types, however, this variation is reversed, and the mixed rows for head length as well as the pure club rows show a smaller percentage of bunt in the bearded than in the beardless segregates.

Incidentally, very resistant rows, very susceptible rows, and numerous gradations between these extremes were found in each morphological type. Probably the large variation in the types shown in Tables 4 and 6 are accidental variations due to the numerous variants under consideration.

SEGREGATION IN THE F_3 ON THE BASIS OF BUNT RESISTANCE.

TABLE 7.—*Distribution of bunt in the different F_3 rows of two crosses which show the genetic segregation of the F_2 plants, the first being the result of crossing two resistant varieties, while the second is the result of crossing a resistant variety on a susceptible variety.*

Total bunt.	Rows of F_3, Turkey × Florence.	Rows of F_3, Turkey × Hybrid 128.	Total bunt.	Rows of F_3, Turkey × Florence.	Rows of F_3, Turkey × Hybrid 128.
Percent			*Percent.*		
None........	72	0	20 to 29.9....	20	9
0.1 to 4.9....	14	4	30 to 39.9....	12	23
5.0 to 9.9....	15	10	40 to 59.9....	12	58
10.0 to 14.9...	11	5	60 to 79.9 ...	4	64
15.0 to 19.9...	9	8	80 to 99.9 ...	2	13

Table 7 shows that bunt resistance is definitely heritable in both crosses, tho the distribution is very different. The 72 immune rows of Turkey × Florence may vary greatly in the amount of resistance they contain, but, since they were all immune, the only way to isolate the differences would be to hybridize each with a susceptible variety and analyze the F_3. This will take time and patience. It is evident, however, that the resistance of the two parents are cumulative in effect, for the parents produced an average of 4.6 percent of infected plants under the same conditions that the 72 immune rows were grown. The 50 rows that produced more than 20 percent of bunt indicate that the resistance of at least one parent is composed of multiple factors, but since between 3 and 4 percent show no resistance (that is, they produced as much bunt as any of the susceptible varieties) it is not likely that there are more than four or five factors affecting resistance in this cross.

The F_3 of Turkey × Hybrid 128 produced a continuous series from one row as resistant as Turkey to 77 which were more susceptible than Hybrid 128. The very small number of highly-resistant

rows indicates a dominance of the susceptibility of Hybrid 128. There is evidently no single or latent heritable factor for resistance in Hybrid 128, for not one out of 194 F_3 rows showed more resistance than Turkey. On the other hand, there must be at least three independent factors for resistance in Turkey. Otherwise, there would have been a larger number of rows as resistant as Turkey. The increased susceptibility of so many rows is difficult to explain, for it is far beyond that of Hybrid 128 grown under similar conditions.

TABLE 8.—*Inheritance of bunt resistance in the F_4 (1919) generation of selections made from the most resistant F_3 rows.*

TURKEY × HYBRID 128.

Row No.	Number of rows in F_4.	Average number of plants per row in the F_4.	Bunt produced in the F_4, average of all rows.	Bunt produced in the F_3 parent row, 1918.	Least bunty row in the F_4.	Buntiest row in the F_4.
			Percent.	*Percent.*	*Percent.*	*Percent.*
1	27	63	13.2	7.0	4.3	26.7
2	26	71	12.7	1.9	5.6	35.0
3	22	56	18.7	4.8	6.5	39.6
4	17	46	34.8	14.6	15.5	54.7
5	14	42	33.2	9.8	11.6	59.5
6	14	66	13.6	6.6	5.6	25.4
7	12	70	25.3	7.1	12.7	40.3
8	8	69	26.6	13.4	16.6	41.7
9	2	50	32.0	6.4	25.9	38.1

TURKEY × FLORENCE.

Row No.	Number of rows in F_4.	Average number of plants per row in the F_4.	Bunt produced in the F_4, average of all rows.	Bunt produced in the F_3 parent row, 1918.	Least bunty row in the F_4.	Buntiest row in the F_4.
1	12	59	.02	0	0	.3
2	11	54	.02	0	0	.2
3	11	44	.97	0	0	3.2
4	7	27	1.97	0	0	5.5

Selections were made from nine of the most resistant rows of the *compactum* type for testing Turkey × Hybrid 128 in the F_4. The results shown in Table 8 indicate that none of the 9 F_3 rows were homozygous for all of the resistant factors. Neither were the 112 F_4 rows as susceptible as Hybrid 128, which produced 98.1 percent of bunt in 1919. Turkey produced 5.9 percent under the same conditions. In fact, all the principal varieties produced a very high percentage of bunt in 1919, which shows that the season was unusually favorable for bunt. With this explanation it would seem that the 1919 record of Table 8 is not so high from an inheritance standpoint as the figures would indicate. The first and sixth selections were probably homozygous for two or more of the units of resistance, for all of the F_4 rows showed a high degree of resistance.

The 41 selections from the 4 rows of Turkey × Florence were all remarkably resistant in 1919, 25 being entirely immune. The most susceptible F_4 row of the 41 was more resistant than either parent. Turkey produced 5.9 percent and Florence 8.1 percent of bunt in 1919, whereas the most susceptible F_4 row produced 5.5 percent.

DISCUSSION AND INTERPRETATION OF RESULTS.

No attempt has been made to find out what resistance is, nor have the conditions of moisture and temperature affecting infection been discussed. The material here presented is on a comparative basis only. The conditions of infection and the time and method of sowing were as similar as possible under field conditions.

The wide differences in the amount of bunt produced in the F_3 under these conditions in comparison with the constancy of the performance of the parent varieties seem to warrant the following conclusions:

1. Bunt resistance in wheat is not a simple Mendelian unit character.
2. Resistance, if Mendelian, is composed of multiple factors, for a continuous series ranging from complete immunity to complete susceptibility has been obtained.
3. Different wheat varieties possess different kinds of resistance.
4. Linkage between resistance and morphological characteristics is not sufficient to prevent the selection of a resistant strain of any morphological type desired.

FIRST GENERATION CROSSES BETWEEN TWO ALFALFA SPECIES.[1]

L. R. WALDRON.

This paper deals with the amount of growth made by certain hybrids between the two species of alfalfa, *Medicago sativa* and *M. falcata*, in comparison with the parent forms, and also with the amount of winter injury and winterkilling sustained by these hybrids. The experiment as planned also concerned itself with the amount of cross-fertilization occurring among normally pollinated alfalfa plants, as reported in a previous paper (4).[2]

EXPERIMENTAL WORK.

The F_1 plants were started in flats in the greenhouse in January, 1918, the seed having previously been treated with sulfuric acid. The plants were transplanted once and very early in the spring were set out of doors in flats. They were protected from severe freezing by cloth. The seedling plants were transplanted to the field during the first week of May.

The soil of the field was a rich, black loam, well drained and in excellent tilth. The plants were set with a hand planter 30 inches apart each way. The progeny of each pistillate parent plant generally comprised 84 or 105 numbers, when the stand was complete. The seedlings planted from the pistillate *sativa* parent and from the pistillate *falcata* parent were 2,316 and 2,034, respectively. A very good stand resulted, tho some blank hills were later in evidence.

The F_1 hybrids from typical plants of the two species of Medicago, such as the parent plants used in this experiment, can be told without hesitancy at time of blooming. The strongly variegated flower color has been described by Westgate (5). The hybrids showed much variation in flower color, but generally only a casual examination was necessary to reveal the characteristic flower color of the hybrid. Notes were taken the first season, 1918, upon each plant as to its

[1] Contribution from the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak. Approved by the Director. Presented at the twelfth annual meeting of the American Society of Agronomy, Chicago, Ill., November 10, 1919.

[2] Reference is to "Literature cited," p. 143.

hybridity and as to the time of the first appearance of bloom. In the spring of 1919, notes were taken on the amount of winterkilling by noting the number of plants dead and alive. An attempt was also made to judge the amount of winter injury suffered by the plants which persisted. The living plants were classified from 1 to 10, grade 1 being given to the weaker plants and grade 10 to the larger and most vigorous plants. The values thus secured will be considered later.

WEIGHTS OF PLANTS.

It was not thought possible or desirable to take weights on all of the plants and so a selection had to be made of the plants to be weighed. One had to consider the possible differential effect of the winter upon the hybrid plants and upon their respective *sativa* and *falcata* parental forms.[3] As will appear later, there seemed to be a difference of this sort, but it is believed it was well guarded against by the method used in selecting the plants. No plants were selected for weighing which had been given a class value less than 5. All of the inferior plants were thus automatically excluded. Even with these plants excluded, there would be a chance for the *sativa* plants scaling above 5 to be depressed in value because of the winter influence. In fact, the modal class of the hybrid plants classified as 5 or above lay at 8, with a mean of 7.7; the modal class of the *sativa* plants lay at 7, with a mean value of 6.9.

It is obvious that, if the hybrid plants produced more growth than the *sativa* plants, this fact would naturally be recorded in the data taken as to the amount of winter injury, which we have been discussing. The amount of winter damage was so slight, as a matter of fact, that the vitiation of the experiment from this source was probably negligible.

In selecting plants upon which weight data were to be taken, those plants which came into bloom very early or very late the season previous were excluded. It is likely that this is a matter of slight importance. The plants from the *falcata* portion of the plat were cut June 19 and 20 and immediately weighed on a scale sensitive to 5 grams. The *sativa* portion of the plat was cut June 24 and 25 and similarly weighed. It is not apparent that this difference in time of cutting had any bad effect upon the experiment.

[3] The comparisons in this experiment, properly speaking, were not between hybrids and their parental forms, but rather between hybrids and offspring of the parents breeding true to the respective specific characters, *sativa* or *falcata*. Comparison was really made between hybrid plants and their half-sibs, as the pistillate parent was known in all cases.

In arranging in series the weights were grouped into classes of 100 grams. The distribution of the frequencies of the four groups is shown in Table 1.

TABLE 1.—*Distribution of frequencies of weight in grams of alfalfa plants, Medicago sativa, M. falcata, and their reciprocal hybrids.*

Plant group.	101–200.	201–300.	301–400.	401–500.	501–600.	601–700.	701–800.	801–900.	901–1000.	1001–1100.	1101–1200.	1201–1300.	1301–1400.	1401–1500.	1501–1600.	1601–1700.	1701–1800.	Total.
M. sativa.....	2	6	24	42	68	68	50	36	17	5	3	1						322
M. sativa × *falcata* hybrids		1	1	6	5	5	19	17	15	11	20	8	4	4	4	1	1	122
M. falcata.....	3	28	50	71	57	50	29	28	9	2	1							328
M. falcata × *sativa* hybrids		6	13	17	24	32	41	23	25	27	12	6	2	3	1			232

The most striking fact about these distributions is the greater ranges of the hybrid plants compared with those of their pistillate parents. This indicates a greater amount of variation among the hybrids than among the parents.

In Table 2 are shown the means, standard deviations, and coefficients of variability, with their probable errors.

TABLE 2.—*Variation constants of weight of plants of Medicago sativa, M. falcata, and reciprocal hybrids.*

Plant group.	Mean.	Standard deviation.	Coefficient of variability.
M. sativa....	636.84 ± 7.04	187.33 ± 4.98	27.27 ± 0.78
M. sativa × *falcata* hybrids.....	964.43 ± 17.78	291.21 ± 12.57	30.20 ± 1.42
M. falcata...........	543.49 ± 7.17	192.65 ± 5.07	35.45 ± 1.04
M. falcata × *sativa* hybrids ..	776.36 ± 11.68	263.80 ± 8.26	33.98 ± 1.18

In Table 2, one notes first that the weights of the *M. sativa* plants are significantly greater than the weights of the *M. falcata* plants. This is probably about what one would ordinarily look for, judging by the comparative amount of growth made by the two species. Data secured by A. C. Dillman at Newell, S. Dak., and at Akron, Colo., and presented by Oakley and Garver (3) show that in nearly all cases plants of *M. sativa* grown individually weigh more than similarly grown *M. falcata* plants. One notes again the very much greater weight of the hybrids over either parent. The difference is so decisive and so striking that the probable errors add but little weight.

The close agreement in the standard deviations of the *M. sativa*

and *M. falcata* plants is very striking. The difference is about the same as either of the probable errors. The standard deviation of either group of hybrids is far in excess of the parents. The average excess of the two groups of hybrids is 46.2 percent, very nearly the same figure as in the case of the means.

In spite of the much greater absolute variability of the hybrids, compared with their parents, the relative variabilities, as expressed by the coefficients, are about the same. This obviously comes about because both the means and standard deviations of the hybrid groups are greater than those representing the parents. The relative variability of the hybrids is intermediate between the two parents. There would seem to be no a priori reason why the hybrid plants should not be more variable than the parents if the latter are in a heterozygous condition, as was obviously the case in this experiment.

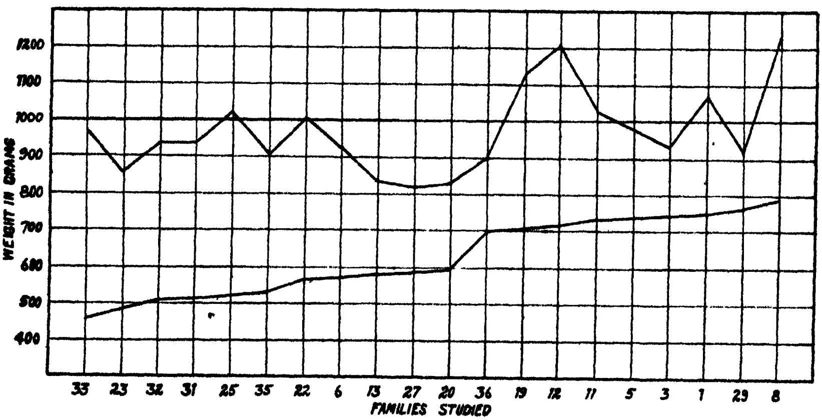

FIG. 10. Weights of plants of *Medicago sativa*, lower line, and hybrids, upper line, from *M. sativa* as a pistillate parent.

As previously stated, the offspring of each plant was planted as a unit. In figures 10 and 11 the weights of the hybrid plants are compared with the weights of their respective parental forms, the latter being plants of *M. sativa* in figure 10, and of *M. falcata* in figure 11. Each abscissa represents the offspring of a known pistillate parent. In all cases one finds the hybrid plants to be heavier than those of their parent varieties. In figures 12 and 13 are presented frequency polygons of the weights of the plants. The solid line in each case indicates the weights of the *M. sativa* (or *M. falcata*) plants and the broken line the corresponding hybrid plants.

In figure 12 a theoretical curve of Pearson's Type I (2) has been fitted to the frequencies of weight of plants of *M. sativa*. This is

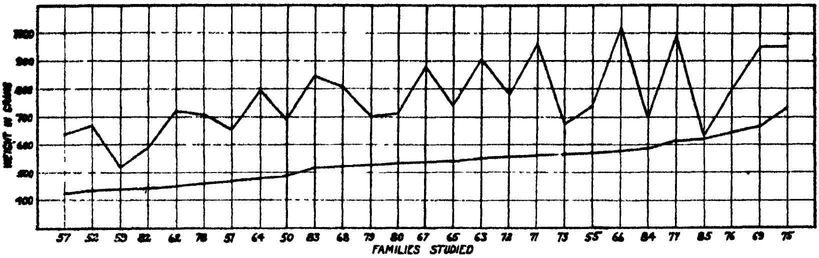

FIG. 11. Weights of plants of *M. falcata*, lower line, and hybrids, upper line, from *M. falcata* as a pistillate parent.

shown by the dotted line. The formula for this curve as developed was:

$$Y = 68.64857 \left(1 + \frac{X}{11.86526}\right)^{31.96119} \left(1 - \frac{X}{47.61236}\right)^{128.25241}$$

The origin was taken at the mode, 614.80. The skewness is positive and equal to .1172. This curve gives a very close fit to the observations. This type of curve seems to be common when one is

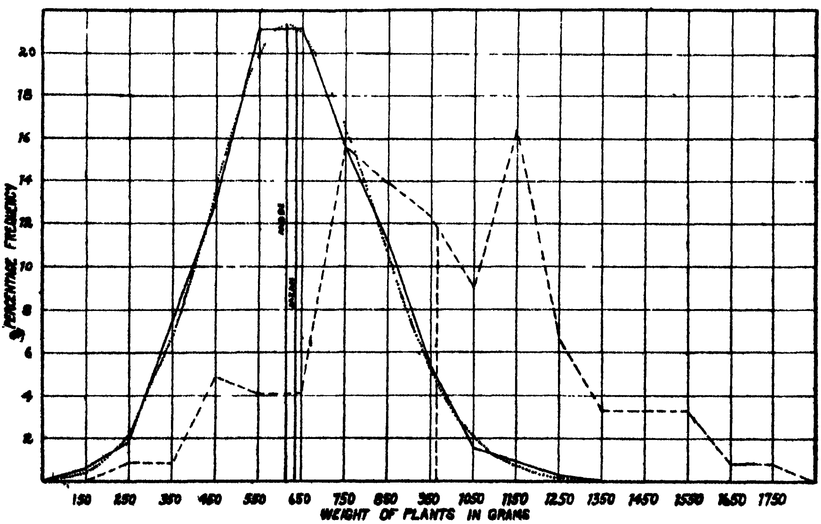

FIG. 12. Variation in weights of plants of *M. sativa*, solid line, and hybrids from *M. sativa* as a pistillate parent, broken line. The *M. sativa* weights are fitted with a Type I curve, shown by the dotted line.

dealing with the weight of plants or parts of plants. I hope to show other examples of this type in data to be presented later. The polygons of the weights of the hybrid plants, in both cases, shown in figures 12 and 13, are quite irregular, with a tendency toward bimodality. The fewer number of hybrid plants would account for some of the irregularity.

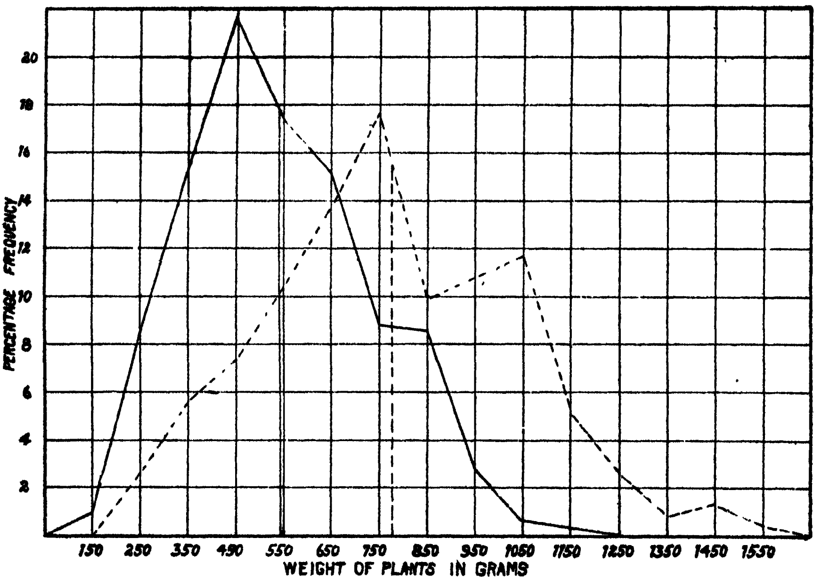

FIG. 13. Variation in weights of plants of *M. falcata*, solid line, and hybrids from *M. falcata* as a pistillate parent, broken line.

The mean of the *falcata* × *sativa* plants is very decidedly less than the mean for the reciprocal hybrids, the *sativa* × *falcata* plants. This difference might be interpreted as being due to differences in soil effects, the two groups occupying either half of a long strip of land. However, the soil was very uniform in character. A study of the differences in plant weights between the hybrids and their parental varieties along the course of the plat indicates that the difference in weight was not due to a difference in soil. Considering each parent plant offspring as a unit and securing differences between the means of the hybrids and their parents in lots of five, we have the following series of means shown in Table 3 distributed along the course of the experimental strip of land.

TABLE 3.—*Mean of differences between hybrids and parents.*

	M. sativa and *sativa* × *falcata*.				*M. falcata* and *falcata* × *sativa*.				
Number..	1	2	3	4	5	6	7	8	9
Means...	311.6	342.4	341.6	386.4	203.3	246.9	354.3	216.5	219.0

While these figures are not conclusive, they indicate rather plainly that there is some intrinsic difference in the yield differences in the two large groups rather than any marked soil difference. Another possible interpretation is that the reciprocal crosses gave different intrinsic results as regards weights of plants. Such a result is so uncommon that it could not well be accepted without excellent evidence. A proper explanation of the disparity in yields as here indicated must evidently await further experimental work.

LENGTH OF STEMS.

A stem was taken at random from most of the plants as they were weighed and laid aside to be measured. It would have been a considerable task to have selected the longest stem in each case. It is probable that with the considerable number of stems used a reasonably good sample has been obtained. The variation constants are presented in Table 4.

TABLE 4.—*Variation constants of length of stem in centimeters in plants of Medicago sativa, M. falcata, and reciprocal hybrids.*

Plant group.	Mean.	Standard deviation.	Coefficient of variability.
M. sativa	85.54 ± 0.67	15.62 ± 0.47	18.26 ± 0.57
M. sativa × *falcata*	87.09 ± 1.09	18.63 ± .77	21.39 ± .93
M. falcata	80.75 ± .64	14.16 ± .45	17.54 ± .58
M. falcata × *sativa*	87.26 ± .86	15.53 ± .61	17.79 ± .72

In this case the stems of *M. falcata* are shorter than those of *M. sativa*. This corresponds to what was found in regard to weight of plant, but the difference is less comparatively than in regard to weight. The length of stems of both hybrid groups is greater than their pure parents, but significantly so only in the hybrids of the *M. falcata* × *sativa* cross.

In regard to the standard deviations, the largest differences are scarcely above the horizon of significance. The standard deviation of the *M. sativa* × *falcata* hybrids is greater than that of the other hybrids for both plant weight and stem length. The coefficients of variability do not correspond to those secured from the weight of

plants and the differences are not of much importance. It is obvious that the greatly increased weight of the hybrid plants over those of the pure species was due principally either to the increased number of stems or to their increased size, or perhaps to both of these factors. No measurements were made on the diameter of stems.

EFFECT OF WINTER INJURY.

As previously indicated in this paper, notes were taken as to the spring condition of stand. Plants were given markings from 0 to 10, the value 1 being given to the weakest plants. These data can not be considered of very great value, as quantitative characters were secured by judging rather than by weighing or measuring. This statement of course does not hold true as to the absolute amount of winterkilling. The distribution of the data is shown in Table 5.

TABLE 5.—*Spring condition of stand in two species of alfalfa and their reciprocal hybrids.*

Group.	Total.	Class value.											Mean.	Coefficient of variability.
		0	1	2	3	4	5	6	7	8	9	10		
M. sativa.	1,942	150	73	61	105	171	235	350	353	259	125	60	5.53 ± .04	46.90 ± .61
M. sativa × *falcata*	168	11	1	0	3	3	13	26	31	33	16	31	7.01 ± .13	36.56 ± 1.50
M. falcata.	1,153	12	10	16	40	118	252	362	205	107	25	6	5.76 ± .02	27.58 ± .24
M. falcata × *sativa*	789	26	6	3	8	16	48	87	178	211	117	89	7.27 ± .05	29.11 ± .53

The percentage of plants winterkilled in each group was as follows:

M. sativa	7.72 ± 0.27
M. sativa × *falcata*	6.55 ± 1.91
M. falcata	1.04 ± 0.30
M. falcata × *sativa*	3.30 ± 0.64

In Table 5 the difference between the means of the plants of the *M. sativa* × *falcata* cross and those of the *M. sativa* parent is quite significant. As I have indicated, this could have come about quite obviously either because the plants of *M. sativa* suffered comparatively more winter injury or because the plants of the *M. falcata* × *sativa* cross were larger, due to heterosis, or both. The first named factor may have entered to some extent, but the latter factor is probably most important. Practically the same relation is seen to exist between the two other means shown in Table 4. The mean of *M. falcata* is quite significantly less than that of the *M. falcata*

$\times$ *sativa* hybrids. In this case, the effect of the winter would tend to offset the heterotic effect of the hybrid plants. Probably another factor enters here quite appreciably. This is the comparatively slow early spring growth of the *M. falcata* plants. When these notes were taken on May 24, the *M. falcata* plants had probably not yet fully awakened from their former dormant condition. The plants of *M. falcata* are later in starting spring growth than are the plants of *M. sativa*. One notes the greater variability of the plants of *M. sativa* and of the *M. sativa* $\times$ *falcata* hybrids than of the other group.

With regard to the percentage killed, significant differences between the group containing the *M. falcata* plants and the other groups are to be noted. These *M. falcata* plants are generally recognized as extremely hardy.

Practical Applications.

When such marked increases in weight are obtained from the F_1 hybrids of the plants of a farm crop, one asks at once if the results can be given practical application in the field. It seems to me that the possibilities in this case must be regarded as rather dubious. The problem resolves itself into two parts, the obtaining of the hybrid seed and the results one may expect in the field after the hybrid seed has been sown.

Considering the use of the parents indicated in this article, one remembers that the seed coming from *M. sativa* as a pistillate parent was hybridized less than 8 percent (4). Seed hybridized only to this extent would scarcely influence the weight of the harvest very appreciably, even if the hybrid plants weighed 50 percent more than the nonhybrid plants. The seed from *M. falcata*, it is true, was hybridized over 40 percent, but the seed production of this species is so meager that it could not be considered from the standpoint of farm practice.

The probability of securing hybrid seed between these two species in sufficient quantity for field sowing seems rather out of the question. There seems to be no compulsory method of obtaining hybrid alfalfa seed, as there is in the case of maize, where one variety can be detasseled.

A greater or less amount of hybridized seed could almost certainly be obtained by growing the F_1 hybrids alternately with plants of *M. sativa*. However, we do not know the amount of increased weight which would accrue with such crosses.

Even presuming that hybridized seed were obtainable, it would be unsafe to reason from the results presented here that the yields under

farm practice would be much increased. The increased plant weights resulted evidently thru an increase in number of stems and it seems evident that this factor could be controlled in considerable measure by differences in rate of seeding. However, if a thin stand were present for any reason, the hybrid plants would evidently be given an opportunity to show an increased weight per plant. The yield per acre would thus be increased. In this connection it should be considered that when alfalfa is grown where water is the limiting factor, as under semiarid conditions, a thin stand insures the greatest success. In such a case one might suppose the hybrid plants would have the larger number of stems per plant, when compared with nonhybrid plants. But when the water available to the plant becomes the limiting factor, one wonders if the tendency for an increase, either in length of stem or in number of stems per plant, would be of much avail toward increasing the yield, except perhaps on certain occasions when the water supply was much above the average. In such a case we would have the machinery present for high yields, ready to function in periods of abnormal water supply. When hybridized seed is once obtained, the resulting crop, it should be remembered, would retain its increased vigor during the life of the plants constituting the crop.

One must consider the possibility of the hybrid plants making a more economical use of water than the parents. I do not know that this point has been investigated for alfalfa, but Briggs and Shantz (1) made eight determinations of the water requirement of maize hybrids in comparison with their parents. The yield of dry matter of the hybrids was notably in excess of that produced by the parents, but the water requirements of the hybrids was essentially the same as that of the parents.

Summary and Conclusions.

This paper deals with weight of plants of the first generation hybrids secured from crossing the two species, common alfalfa, *Medicago sativa*, and yellow-flowered alfalfa, *M. falcata*.

The hybrids showed a much greater weight per plant than either the *M. sativa* or *M. falcata* plants grown under similar conditions. This increase in weight was 47.5 percent. The absolute variability of the hybrids was much greater than of the parents.

Data on length of stems were taken of the hybrid and the nonhybrid plants. Significant differences were not shown. The increased weight per plant was then probably due to the increased number of stems per plant.

Winter injury was comparatively slight, but the plants of *M. falcata* showed significantly less killing than the other groups.

While such an effect of increased vigor thru hybridization might be put to profitable field practice in such a crop as maize, it is not evident that this can be done with alfalfa because of the difficulty of securing the hybridized seed.

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3. OAKLEY, R. A., and GARVER, SAMUEL. *Medicago falcata*, a yellow-flowered alfalfa. U. S. Dept. Agr. Bul. 428. 1917.
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5. WESTGATE, J. M. Variegated alfalfa. U. S. Dept. Agr., Bur. Plant Indus. Bul. 169. 1910.

TEMPORARY ROOTS OF THE SORGHUMS.[1]

JOHN B. SIEGLINGER.

Determinations of the number of temporary roots[2] and secondary rootlets[3] have been made for the common cereals, wheat, oats, barley, and corn. In connection with an investigation dealing with root development of the sorghums, it was found desirable to learn the number of temporary roots of certain varieties of this plant. The varieties used were Sunrise kafir, Dwarf milo, feterita, Manchu kaoliang, and Acme broomcorn. The studies reported were conducted in the greenhouse at the Woodward Field Station, Woodward, Okla., during the winter of 1919–1920.

A preliminary experiment consisted of germinating 100 kernels of each of the five varieties of sorghum between blotting paper. After 13 days the germinated seed were counted and the seedlings examined

[1] Contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication February 17, 1920.

[2] Wiggins, Roy G. The number of temporary roots in cereals. *In* Jour. Amer. Soc. Agron., v. 8, no. 1, p. 31–37. 1916.

[3] Walworth, E. H., and Smith, L. H. Variations in the development of secondary rootlets in cereals. *In* Jour. Amer. Soc. Agron., v. 10, no. 1, p. 32–35. 1918.

to determine the number of temporary roots. The results obtained are presented in Table 1.

TABLE 1.—*Germination of five varieties of sorghum and number of temporary roots on each seedling.*

Variety.	C. I. No.	Number of kernels sown.	Number germinated.	Number of temporary roots per seedling.
Sunrise kafir	472	100	84	1
Dwarf milo	332	100	92	1
Feterita	182	100	99	1
Manchu kaoliang	171	100	86	1
Acme broomcorn	243	100	84	1

As noted in Table 1, only one temporary root, the radicle, developed on any seedling.

Five hundred kernels of each of the five varieties of sorghum were then sown in a greenhouse bed of screened river sand. The seed germinated well and the plants apparently made normal growth. Plants were dug and the roots washed out. Over 100 seedlings of each variety were examined at different times and in every case the radicle was the only temporary root present.

Later, one hundred kernels each of the five varieties of sorghum and a like number of kernels of Kanred wheat and Mexican June corn were sown in a bed of sand. On the ninth day after seeding more than half of each row was dug and the roots washed out and examined. The results obtained are shown in Table 2.

TABLE 2.—*Seedlings of wheat, corn, and various sorghums grouped according to the number of temporary roots, the total number of seedlings and temporary roots, and the mean number of temporary roots to the seedling.*

Variety.	Numbers of seedlings falling into classes having following numbers of temporary roots.							Total number of seedlings examined.	Total number of temporary roots.	Mean number of temporary roots.
	1	2	3	4	5	6	7			
Kanred wheat		2	20	25	11			58	219	3.77
Mexican June corn		1	6	30	15	8	1	61	270	4.42
Sunrise kafir	42							42	42	1.00
Dwarf milo	63							63	63	1.00
Feterita	41							41	41	1.00
Manchu kaoliang	46							46	46	1.00
Acme broomcorn	34							34	34	1.00

The results shown in Table 2 indicate that sorghums of the milo-durra, kafir, kaoliang, and broomcorn groups have but one temporary

root, the radicle. These results were obtained under conditions in which Kanred wheat produced a mean of 3.77 temporary roots to the plant and Mexican June corn a mean of 4.42 temporary roots to the plant (radicle included).

In sorghums, as with other cereals, the radicle appears first, then the plumule. The radicle develops several branch roots. In sand cultures, three or four days after the plumule appears at the surface, the first node is distinctly developed at about a half inch below the surface of the soil and from this node a whorl of permanent roots is gradually developed. After the permanent roots begin to function, the temporary root soon decays.

Summary.

Studies of the root development of certain varieties of sorghum under greenhouse conditions have shown that:

1. The radicle is the only temporary root developed in sorghums.
2. Shortly after germination the first node develops below the surface, and from this node the first permanent roots develop.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the March issue was 524. Since that number went to press, 13 new members have been added, 2 lapsed members have been reinstated, 7 members have resigned, and 1 has died, making a net gain of 7 and a present membership of 531. The names and addresses of the new and reinstated members, the names of the members resigned or deceased, and such changes of address as have come to the notice of the officers, follow:

New Members.

Barnes, Earl E., Dept. of Soils, O. S. U., Columbus, Ohio.
Briggs, Fred N., 122 Hilgard Hall, Berkeley, Cal.
Crist, Henry, Farm Crops Section, I. S. C., Ames, Iowa.
Dickey, J. B. R., State College, Pa.
Gooding, T. H., Agr. Expt. Sta., Lincoln, Nebr.
Hurst, L. A., 2001 Sixteenth St. N. W., Washington, D. C.
Kondo, M., Ohara Agr. Inst., Kurishiki, Okayama, Japan.
Lindstrom, E. W., Dept. of Genetics, U. of W., Madison, Wis.
McCool, M. M., Soils Dept., Mich. Agr. College, East Lansing, Mich.

OWENS, J. S., 426 E. College Ave., State College, Pa.
SCHERTZ, F. M., 1305 Farragut St. N. W., Washington, D. C.
TAYLOR, J. W., 1116 Tenth St. N. W., Washington, D. C.
TRACE, CARL F., 331 N. 17th St., Manhattan, Kans.

MEMBERS REINSTATED.

HURST, J. B., Medford, Okla.
WOOD, CASPER A., College Station, Texas.

MEMBERS RESIGNED.

ABELL, M. E.,
BANCROFT, ROSS L.,
BIRCHARD, F. J.,
CLEVENGER, C. B.,
ERDMAN, LEWIS W.,
HALL, THOMAS D.,
WILLEY, LEROY D.

MEMBER DECEASED.

BAKER, JOHN W.

CHANGES OF ADDRESS.

BOYACK, BREEZE, Thompson Falls, Mont.
CLARK, CHAS. F., Presque Isle, Maine.
DAVIS, L. VINCENT, 340 S. Lumkin St., Athens, Ga.
LANGENBACHER, R. A., County Agent, Macon, Mo.
McGUFFEY, C. CARL, 308 E. Lincoln St., Ada, Ohio.
PETRY, EDWARD J., 1218 E. Catherine St., Ann Arbor, Mich.
RAST, LOY E., 408 Continental Bank Bldg., Shreveport, La.
RICHARDS, PHIL E., Morganfield, Ky.
STEWART, H. W., New Soils Bldg., College of Agr., Madison, Wis.
WEEKS, CHAS. R., State Farm Bureau, Manhattan, Kans.
WOODARD, JOHN, Hull Botanical Lab., Univ. of Chicago, Chicago, Ill.

A NEW COMMITTEE ON VARIETAL STANDARDIZATION.

On recommendation of the Committee on Varietal Nomenclature at the Chicago meeting last November, the Society voted to disband the old committee and recommended the appointment of a new committee on standardization of varieties. The functions of this committee are stated on page 350 of the December issue of the JOURNAL. The new Committee on Varietal Standardization has just been named by President Harris, as follows:

R. A. Oakley, U. S. Dept. Agr., Washington, D. C., *chairman.*
J. H. Parker, Agr. Expt. Sta., Manhattan, Kans.
H. K. Hayes, University Farm, St. Paul, Minn.
E. F. Gaines, Agr. Expt. Sta., Pullman, Wash.
H. H. Love, Cornell Univ. Agr. Expt. Sta., Ithaca, N. Y.

H. S. Hastings, Atlanta, Ga.
George Stewart, Agr. Expt. Sta., Logan, Utah.
J. Allen Clark, U. S. Dept. Agr., Washington, D. C.
A. B. Conner, Agr. Expt. Sta., College Station, Texas.
L. H. Smith, Agr. Expt. Sta., Urbana, Ill.

NOTES AND NEWS.

H. H. Biggar, scientific assistant in the Department of Agriculture, who has been engaged in studies of corn root and ear rots at Bloomington, Ill., for the past year, has resigned, effective April 30, to become associate editor of *The Northwest Farmstead* and *Dakota Farmer*, with headquarters at Minneapolis.

Breeze Boyack, assistant agronomist at the Colorado station, has resigned to engage in ranching in Montana.

A. E. Ewan, superintendent of experimental fields at the Kentucky station, resigned December 13, 1919, and was succeeded by S. C. Jones.

T. E. Keitt resigned January 1 as chemist and agronomist of the Georgia station.

C. S. Knight, dean of the college of agriculture of the University of Nevada and agronomist of the Nevada station, has resigned, effective June 30, to become secretary of the Reno, Nev., Chamber of Commerce.

D. R. Johnson, assistant professor of agronomy at the Oklahoma college and station, resigned February 15 to accept a position at the Iowa college.

Ivar Mattson, superintendent of the Tribune (Kans.) Branch Experiment Station, has resigned and has been succeeded by G. E. Lowery, formerly agricultural instructor in the high school at Tribune.

E. G. Montgomery, professor of farm crops in Cornell University, is on six months' leave of absence and is now in charge of the Foreign Markets Service of the Federal Bureau of Markets.

J. W. Nicolson, secretary of the Michigan Crop Improvement Association, is now manager of the seed department of the Michigan State Farm Bureau.

Chas. R. Weeks, for the past four years superintendent of the Hays (Kans.) Branch Station, has resigned, effective May 1, to become secretary of the Kansas State Farm Bureau, with headquarters at Manhattan.

Leroy D. Willey, superintendent of the Sheridan, Wyo., Field Station, has resigned and has been succeeded by R. S. Towle, formerly of the Northern Great Plains Field Station, Mandan, N. Dak.

Meeting of Advisory Board.

The Advisory Board representing the American Society of Agronomy on the Division of Biology and Agriculture of the National Research Council met in Washington, D. C., March 19 and 20, and presented matters of interest to agronomists to Chairman McClung. The action of the Council will be reported at a later date. The meeting was attended by C. V. Piper, *chairman*, Dr. J. G. Lipman, Prof. C. A. Mooers, and Prof. L. E. Call.

The Division of Biology and Agriculture of the National Research Council is composed of representatives of the American Society of Agronomy, the American Society of Bacteriologists, the Botanical Society of America, the American Genetics Association, the American Society for Horticultural Science, the American Phytopathological Society, the Society of American Foresters, the Society of American Zoologists, and the Ecological Society of America, with eleven members at large. The executive committee of the Division consists of Dr. C. E. McClung, professor of zoology in the University of Pennsylvania, *chairman;* Dr. L. R. Jones, professor of plant industry in the University of Wisconsin, *vice-chairman;* I. W. Bailey, professor of forestry at Bussey Institute; F. R. Lillie, professor of zoology in the University of Chicago; G. R. Lyman, pathologist in the U. S. Department of Agriculture; H. F. Moore, deputy commissioner of the U. S. Bureau of Fisheries; and Dr. A. F. Woods, president of Maryland State College.

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GUAM CORN.[1]

GLEN BRIGGS.

Corn (maize) is one of the principal food crops of the Island of Guam. It is not a native plant, but was introduced from Mexico nearly 250 years ago. During these two and a half centuries it has been grown by a people who do not practice, nor even understand, any method of improving corn. Guam corn is a variety which has been found to be well adapted to the tropical conditions existing in some of the Pacific Islands and particularly in Guam. Locally, it is known as native corn. Until recently, it received no attention in the way of improvement.

While no evidence can be brought forward to prove the claim, it is more than probable that the corn, by a process of evolution, has changed considerably from the original introductions, as almost certainly it has been kept largely free from mixtures. Recently, however, among certain of the natives a superstition has developed that a slight yellow mixture will keep away disease and insect pests. Many introductions of corn from the mainland of the United States and from over forty tropical countries have been made at various times since the American occupation of the island. None of these has proved to be so well adapted to tropical conditions nor to local environment as the Guam corn.

Only one type of corn is grown on the island, the present crop being estimated as approximately the 486th in the process of evolution. This assertion is based on careful study of the early history of the

[1] Contribution from the Guam Agricultural Experiment Station, Agana, Guam. Received for publication February 28, 1920.

island. The first mention of corn growing in Guam is found in the annals of the early mission, where it is related by Padre Garcia (2; 7, p. 402)[2] that on the night of October 15, 1676, the natives destroyed a field of maize which was the principal sustenance of the missionaries and soldiers. Two years later, it was said that the natives were becoming fond of maize, altho they did not make bread of it, not having implements for its preparation.

In Guam the principal planting season is in April or May, the second crop being planted in November or December. The time of planting depends upon favorable weather conditions. The first crop matures during the season of light rains which precedes the heavy rainy period; the second crop is grown in the season following the heavy rains and matures during a favorable drying season. About 120 days are required to mature a crop. From these data it is seen that about 243 years have elapsed since corn growing in Guam was first mentioned and, inasmuch as it is and has been a common practice of the Chamorro people (natives of the Mariana Islands) to save the seed of the preceding crop for future planting, the present corn crop is attaining its 486th cycle. Another reason why the corn is nearly always planted from the preceding crop is that the seed rapidly deteriorates in this humid climate, or is subject to attack from weevils which are very prevalent. These facts make it almost impossible for the farmer to keep his seed an entire year and, until recently, there were no storage facilities for seed.

Crozet (4), who visited Guam in September, 1772, gives Tobias, then the Spanish Governor of Guam, credit for having introduced corn into Guam. This is a mistake, as Padre Garcia's record was made nearly 100 years before. However, it is certain that Tobias encouraged the cultivation and use of maize more than former governors. It remained for Felipe de le Corte, Governor of Guam from 1855 to 1866, to encourage larger plantings and to study means of preserving or storing corn in large quantities from one season to the next. During this time underground granaries were established upon the island. The remains of one with the grinding implements are still to be seen near Inarajan.

That there was probably no corn on the island in the early days is shown by the fact that the Dutch expedition (7, p. 13), under Oliver Van Noort, touched at Guam in 1600 on its way from the South American coast to Manila and obtained supplies, but no corn was mentioned among the provisions brought on board. The noted naturalist, William Dampier (5), speaks of the crops growing in Guam

[2] Reference is to "Literature cited," p. 157.

before the eighteenth century, but does not mention corn in his list of several cultivated plants. Later, Anson (1) visited the Mariana Islands and spent some time there, but, altho he speaks of many of the plants growing on the islands, he does not mention corn. While the old records show that corn was growing on the island before both of these two last-mentioned men visited Guam, it surely was not in large areas, nor was it largely used as food by the natives.

No doubt the present corn was originally introduced from Mexico by the Jesuit missionaries, all the evidence being strongly in favor of that theory. No earlier records than that of Padre Garcia mention corn.

Many of the words commonly used in connection with the means of preparing corn for food are purely Mexican. It is well known that the original home of many plants can be very accurately determined by their vernacular names. Many of the names and uses of a plant are identical, or associated in some way, with the names in common use in the country from which they were obtained. In some cases, the names are slightly modified to conform to the language spoken in the new country. Again, the original spelling of certain Mexican words which are connected with certain practices in the preparation of corn for food has been retained, while in other instances the spelling has been changed to conform to the Chamorro language.

Corn is used largely in the form of tortillas, a flat thin cake which is rolled into a paste and baked on a griddle. The word "tortilla" is purely a Mexican term, but has been corrupted into "titiyas" to conform to the Chamorro pronunciation, or inflection. Along with this method came the Mexican instruments, the "metate" and the "mano" used in the preparation of corn. The former is a low-curved grinding stone generally raised on three short legs. The latter is a stone rolling-pin or hand grinder, which may be either cylindrical and slightly tapering at each end, or more nearly square with both a coarse and a fine grinding surface. The spelling and pronunciation of these Mexican words have been adopted by the Chamorro as well as their use. The griddle, formerly made of earthenware and now sometimes made of iron, is called "comat" by the Chamorro people. The Mexican term is "comal" but, as a final "l" is always changed to a "t" by the Chamorro people, the same name is used, tho it is slightly modified to meet the local conditions. Further proof that corn did not come from other countries is evidenced by the fact that foreign words, other than the few Spanish words and the terms and instru-

ments used by the Mexicans, do not appear in the Chamorro language. The following are the few words used: "Gugan," a word meaning to shell or shelling; "fugo," meaning to break (in doubling the stalks); "gulic" and "pasa," terms meaning rough and fine grinding, respectively, the latter also being used to mean the change of the corn to the paste form in making torillas; and "coco," a Chamorro word meaning to harvest, to reap, or to gather in the harvest.

A number of practices used in the cultivation of corn are also evidently adopted from the Mexican customs. Corn is broken over, or the stalk doubled just below the ear, when the kernels show some signs of hardening. This simple and effective method leaves the ears with the point hanging downward, prevents water from collecting under the husks where it would cause germination or rotting of the grain, and also hastens the maturity of the crop. In reality, it prevents the loss of the crop in this climate of high temperature and frequent rains. This operation, which is still practiced in some parts of southern Mexico, was evidently introduced from that country by soldiers from Mexico who were doing duty in Guam.

In Guam, corn, when prepared for the table, is soaked overnight in lime water. This process, which in Chamorro is known as "yaca," softens and loosens the husk or hull until it can be readily removed. The corn is then washed in cold water, when the whole outer hull is removed. It is then ground to a paste between the two grinding stones and made into thin cakes, being baked in the same manner as are the Mexican tortillas.

Another fact which indicates the introduction of corn from Mexico is that for the first one hundred or more years after the discovery of the islands, all ships from Mexico sailed from the port of Acapulco to the Philippine Islands, and touched only Guam, or the Mariana Islands, on the outward trip. On their homeward trip, they went far to the North in order to avoid the adverse trade winds. The routes followed by these ships probably more largely account for the introduction of corn from Mexico alone than does any other fact.

An interesting feature in the evolution of the Guam corn is the entire lack of seed selection generally practiced in the more modern methods of agriculture. For nearly 250 years this corn was planted season after season with no thought given to the selection of the best ears or to those growing on the best stalks in the field. Nevertheless, the corn conforms more nearly to a type as regards kernel, ear, and stalk, than any other variety seen by the writer in the corn belt of the United States or elsewhere. While methods of improvement are not

practiced by the natives, it must be acknowledged that these people do very carefully select the largest and best kernels after the corn is shelled and dried and save these for seed for the next planting. This practice has resulted in a more fixed type of kernel than is commonly found in other varieties; the fact remains, however, that this corn has almost become a fixed type, due either to a general mass selection, or to evolution, and probably to both. Recently some mixture has occurred from importations, but this has not been great enough to alter the fixed characteristics already established thru the 250 years of growing one kind of corn.

While different writers have varied greatly in their descriptions of the Guam corn, all have agreed that there has been and is only one variety commonly grown on the island. Crozet (4) says: "The cultivation of maize especially gives incredible results. It is common to find on the maize fields plants 12 feet high, with eight or ten cobs, 9 to 10 inches long, well stocked with good nourishing grain." Safford (7, p. 402) says that "only one variety of maize is successfully grown on the islands. It is soft-grained and white, resembling that which is most common in Mexico." Thompson (9) has stated that "prior to introductions recently made by this station there was but a single variety on the islands, a hard flinty, white corn with broad, shallow grains and a large white cob." Hartenbower (6), in a picture of the type of corn used in improvement experiments at the Guam Experiment Station, shows it to have a large and apparently soft kernel in which a small dimple can be seen. He also states that

normally the stalks are relatively low growing, about 5 or 6 feet in height, and most stalks bear two small ears. The shanks are large and, as with most other crops grown in the Tropics, there is a large amount of foliage. There is no uniformity in size or shape of ear, an outcome of a lack of selection or other improvement. In size the ears would be classed as decidedly small, perhaps averaging 5 inches in length, while in shape there is little taper from butt to tip. Both grain and cob are normally white, showing little variation in color. The space between the kernels on the cob is large, and this, with shallow kernels and large cobs, makes a low percentage of grain to cob.

Costenoble (3) states that "ordinarily this variety produced ears of fair size, but with a single ear to the stalk. It is seldom that a stalk is found bearing two or more ears." He was making selections with a view to developing a type which would have two or more ears to a stalk. It seems hardly possible that this could be accomplished in the short time elapsing between his report and that of Hartenbower, or for the corn to again undergo so complete a change within

the next three or four years. At present the corn is not of either type, but has a larger percentage of single-ear stalks than it has with two ears to a stalk. This fact seems to be true of all the fields, or at least of a large number visited by the writer. In regard to Crozet's description many of his representations are overdrawn and for that reason should be largely discredited.

As to the difference noted between flint and soft corn, it would appear that the writers just mentioned failed to investigate fully the corn on the island, for both types exist, the soft corn occurring in much the larger quantity. This corn, which is more easily prepared for food, is preferred by the native people, who select it for seed. In all probability it has been and still is the type most commonly planted. Probably the difference in descriptions quoted is due to the lack of any definite data upon which to base conclusions. With a view to obtaining accurate information, the writer made some investigations and gathered considerable data on the Guam corn which seems to be one of the best tropical corns yet developed in the Mariana and Hawaiian Islands (8). It has shown much promise in the Philippine Islands, and may prove adapted to other similar locations.

The stalks of the Guam corn are only medium in size and height, are well proportioned, and bear few, if any, suckers. They gradually taper from the bottom to the top, and bear the ears midway the stalk. The average height of 2,112 nonselected stalks, taken from various fields, was 7.58 feet. The height of the ears from the ground was 3.83 feet, while it was found that the average number of nodes below the ear was 7.4 and above the ear, 4.8. In general, the stalks have approximately 12 leaves each.

After selection of this corn thru 10 generations for early maturity, uniformity of type, and for one ear to a stalk, the data show that, in 850 measurements, the average height of the plants was 6.02 feet, the ears were only 2.46 feet from the ground, and the average number of nodes had been reduced only by a half node. While no actual figures are available in regard to the size of the ears in this experiment, observations revealed the fact that they had also decreased in size.

Most of the ears are well covered by shucks, which are not quite long enough to furnish ample protection from weevils. In general appearance the ears all seem to be cylindrical; however, actual data, based on a study of 318 ears which were gathered at random from several fields, showed that 57.86 percent were cylindrical, 26.72 percent were slightly tapering, and 15.41 percent could be classed as tapering. The average length of a large number of field-run ears was

6.46 inches and the circumference, 6.92 inches. The ears would all be classed as short, but large in diameter. The cob is large and white with a large shank.

Almost without exception the butts are flat, as is shown by the following data: 97.48 percent flat; 1.26 percent rounding; 0.94 percent well filled over end; and 0.31 percent with swelled butts. The tips are not well covered and, in some cases, are more or less exposed, showing a considerable amount of protruding cob. This protrusion is probably the greatest weakness of the corn and, to a certain extent, seems to be associated with the long shuck which covers the tips. The results show 98.11 percent of the ears with a protruding cob either to a greater or less extent; 1.26 percent of oval, well-covered tips; and 0.31 percent each of swelled and well-filled tips.

The rows on the ears are fairly straight, strongly paired in arrangement, and number, as a rule, ten. Sometimes 8, 12, and as many as 14-row ears are found. The 8-row ears are very strongly paired and the space between the pairs is very wide and deep; the width and depth decrease as the number of rows increase. In an experiment conducted by the station, it was found that the number of rows varied only slightly in two generations due to selection. Table 1 shows the results.

TABLE 1.—*Effect of selection on rows of kernels to ear.*

Class.	Number of ears harvested from							
	General selection.		8-row selection.		10-row selection.		12-row selection.	
	No. of ears.	Percent.	No. of ears.	Percent.	No. of ears.	Percent.	No. of ears.	Percent.
Total	706	100.00	280	100.00	365	100.00	416	100.00
With 8 rows.	196	27.76	53	18.93	81	22.18	78	18.75
With 10 rows.	475	67.28	193	68.93	270	73.97	284	68.27
With 12 rows.	34	4.82	33	11.78	12	3.28	49	11.78
With 14 rows.	1	0.14	1	0.36	2	.57	5	1.20

The rows are loose on the cob when the corn is well dried. However, it is seldom that the corn is dried on the cob; as a rule, it is harvested before it reaches maturity and is shelled by hand before the kernels harden. The cobs are large and dry very slowly. On account of the humid weather conditions in Guam it is rather difficult to dry the corn while it is still on the cob. Usually, the germs die and turn black, and yellow and blue molds form between the kernels and the cob.

In finding the shelling percentage of the Guam corn, selections were

made of 8, 10, and 12-row cars with the following results: 8-row selections, 67.4 percent; 10-row selections, 68.6 percent; and 12-row selections, 65.8 percent. The last named appeared at first to be contrary to expectations, but it was discovered that altho the shelling percentage of the 12-row ears was less than the others, the total yield of the corn was greater, being 17.8 percent greater than the 8-row and 1.3 percent greater than the 10-row ears. The average weight of 1,378 ears, taken as they were picked from the station field, was 0.5 pound each. The average yield of corn at the Guam Station during 1917 was 37.5 bushels per acre, and during 1918, 37 bushels. While these are not phenomenal yields, they are considered to be fair under tropical conditions.

The kernels of the Guam corn are broad, square, with slightly rounded shoulders, and almost parallel on the edges. They have smooth crowns which are slightly dimpled. In general, the kernels are called shallow in depth, but in reality they are medium, being almost a half inch deep. In measuring 1,883 kernels taken from non-selected corn just after it was shelled, it was estimated that it took an average of 2.11 kernels to make an inch. The kernels are slightly greater in width than in depth. On the average, 16,003 kernels measured 2.02 kernels to the inch, or a width of almost half an inch to a kernel. In measuring the thickness of kernels, it was found that 2,393 kernels averaged 5.44 kernels to the inch. All were very uniform in shape and size, the only variation being in those kernels near the butts or tips. In weighing a large number of selected kernels for planting, it was found that 23,856 weighed 8,814.8 grams, or an average of 36.95 grams per 100 kernels. In a lot of field-run seed it was found that 28,918 kernels weighed 10,844.8 grams, or an average or 37.5 grams for each 100 kernels, showing that the kernels must all be about the same weight.

In a varietal experiment conducted in 1912 at the Guam Experiment Station, 74 varieties from over 40 tropical countries were under test. Thompson (9) says,

> the corn grown in this test represented a wide variety of types, grading from the small-grained, flinty, variegated corns from India, Ceylon, Burma, and Formosa, to the large-grained, soft floury mummy corn from Ecuador and Colombia. These two groups, representing the extremes with regard to hardness of grain, are also most widely variant in size of kernels, the group from southern Asia requiring from 200 to 220 grains to weigh an ounce, while a variety from Ecuador required 55 grains to constitute an equal weight.

Among these varieties only two were promising, one, No. 576, from

the island of St. Vincent, and the other, No. 589, a very similar variety obtained from St. Lucia. These were earlier than the Guam corn, but otherwise had no advantage over it. Later this seed was lost. The Guam corn has proved in a large number of tests to be superior to other varieties when grown in Guam, and in the Hawaiian and Philippine Islands, and for this reason should be grown more widely than it is at present.

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THE UNRELIABILITY OF SHORT-TIME EXPERIMENTS.[1]

F. S. Harris and N. I. Butt.

Young experimenters are likely to be very enthusiastic over their discoveries. After obtaining results covering a year or two, the temptation is to rush into print and proclaim to all the world findings that seem perfectly clear. If restraint is exercised, the chances are that what seemed to be trustworthy results are completely upset by some later year. Discoveries that seemed so certain are spoiled by irregularities brought in by additional investigations. It is very easy to formulate a law on the first set of data, but the trouble is that the law is likely to cease operation when put to later tests.

Unusual results that are likely to lead to early fame offer a particularly strong temptation for hasty publication. Glancing over the more important results of agricultural experimentation, however, the list is singularly free from revolutionary discoveries. Most of the sensations have been caused by the presentation of results covering only a short time. A seemingly perfect correlation is frequently found because the number of variates is so few that all conditions are not represented. The complications in ordinary agriculture are so great that precision can scarcely be expected. It is not at all uncommon to find variations of 100 percent in the average yields of crops; sometimes several years in succession will show an average of nearly this much above the average of a long period. Were it possible to eliminate experimental error, these variations would make very little difference in many comparative experiments, but experimental error will creep into even the most careful trials. A small error in an exceptional year may affect the results of the experiment for several succeeding years. Treatments affecting the moisture condition of the soil are especially subject to fluctuations caused by years in which the climatic conditions are widely different from the normal.

Experimental Results.

In order to show the extent of fluctuations in yields during different years, the influence of these fluctuations on results variously summarized, and the specific dependence that should be given to data

[1] Contribution from Utah Agricultural Experiment Station, Logan, Utah. Received for publication February 25, 1920.

obtained in a given length of time, a number of experiments conducted by the Utah Agricultural Experiment Station have been studied from several different angles. It is thought the results are of general interest in helping to stabilize experimental material.

The experiments were, for the most part, carried on at the Greenville Experiment Farm near Logan, Utah. The soil is a deep, sandy loam, rich in lime. The detailed composition of the soil is shown in Utah Agricultural Experiment Station Bulletin No. 115.

To make comparisons, the average results of each test for the period were found and the variation in percentage of each year's results from the average determined. This reduces the data to a common basis so that comparisons may be easily made.

FLUCTUATIONS IN IRRIGATION EXPERIMENTS.

In Table 1 is shown the variation from the average yield of sugar beets in a typical irrigation experiment covering the years 1904 to 1919, inclusive. While the results in the different tests are not strictly comparable in every case because the years considered are not the same, the number of years averaged is great enough to eliminate serious error.

TABLE 1.—*Percentage variations from the average yield of sugar beets as affected by different quantities of irrigation water.*

Year.	Inches of water applied.				
	0	5	10	15	20
1904		−41	−9	−18	
1906			24	28	
1907			24	19	16
1908			2	11	6
1909	15	24	−12	−24	−18
1910			−8	−15	−9
1911			−8	−14	10
1912	1	−1	8	−4	−18
1913	23	53	24	22	23
1914	27	11	24	35	22
1915	−22	−11	−38	−17	−9
1916	−7	−3	−12	−3	−15
1917	−5	2	−6	−2	−19
1918	28	13	7	14	−13
1919	−61	−47	−20	−32	
Average variation	21	21	15	17	15
Average yield, tons	12.4	15.0	19.5	21.0	23.0

From Table 1 it is seen that while on the average the crops receiving least water varied most there is a tendency for the variations with

the different irrigation treatments to be in the same direction and somewhat the same during the same year. In some years, as in 1913 and 1918, there is very close correspondence of most of the variations. In others, such as 1915 and 1919, there is considerable divergence, altho they are in the same direction. It will be noted that in years of wide variation between the treatments, the same treatment does not always hold the same relative position in different years. For instance, the 10-inch irrigation varied most from the average in 1915 whereas in 1919 it varied least of the treatments. Conclusions drawn from the experiment for a short period which included only one of these years of wide divergencies, especially if it came in a year of exceptionally large yields as in 1914, might be considerably different from what it would be with sufficient time to include years with an opposite divergence.

Data regarding the yield of ear corn in an irrigation experiment are presented in Table 2. The object of giving this material here in connection with Table 1 is largely to show that the deviations between the treatments for different crops are not the same for the same years. Irregularities which might interfere with the correct interpretation of the results are seen here as with sugar beets.

TABLE 2.—*Percentage variation from the 9-year average yield of ear corn as affected by different quantities of irrigation water.*

Year.	Inches of water applied.					
	0	5	10	20	30	40
1911	−28	−29	−17	−12	− 8	6
1912	19	6	− 5	− 7	4	3
1913	28	20	32	22	11	24
1914	− 4	9	−11	− 6	− 1	2
1915	−20	−20	− 4	1	0	−20
1916	3	3	0	− 5	− 3	− 8
1917	16	8	23	5	10	9
1918	21	36	20	23	−15	11
1919	−34	−35	−37	−22	−28	−26
Average variation.	19	18	16	11	9	12
Average yield (bu.)	75.5	87.7	83.9	88.7	89.9	82.8

From the two irrigation experiments just cited we may conclude that the variation in yields of the different treatments from their averages are very nearly alike for the same crop during the same year. Therefore, much of the rest of the material of this paper will be presented with only one or two typical moisture treatments in order that the data will not be too voluminous.

FLUCTUATIONS IN MANURING TESTS.

In Table 3 are shown results secured in manuring tests with corn where no irrigation water was added and with a 20-inch annual application, the plats being duplicated in each case. Variations between the different manurings are somewhat wider than between the different irrigation treatments just discussed. Moreover, the years do not show a consistent relative variation between the manurings, the 15-ton manuring showing greatest fluctuations one year and least another. The average variation shows that the 15-ton manuring does not hold so close to the average as the unmanured or the one manured at the rate of 5 tons and that the average variation with the heavy manuring is proportionately greater when not irrigated than when irrigated.

TABLE 3.—*Percentage variations from the 9-year average yield of ear corn as affected by different quantities of manure.*

Year.	Unirrigated.			20-inch irrigation.		
	Tons manure applied per acre.			Tons manure applied per acre.		
	0	5	15	0	5	15
1911	−10	−28	−21	−14	−12	7
1912	−14	19	26	−4	−7	−3
1913	24	28	39	7	22	26
1914	−11	−4	19	−4	−6	−8
1915	−24	−20	−34	−21	1	−8
1916	3	3	−3	−9	−5	−6
1917	12	16	12	15	5	4
1918	43	21	25	28	23	27
1919	−25	−34	−62	2	−22	−39
Average variation	18	19	27	12	11	14
Average yield (bu.)	54.7	73.5	72.9	73.1	88.7	95.3

With corn, as with other crops, there are cycles of two or three years of comparatively high yields followed by similar cycles of low yields and years of large variations between treatments followed by years of small variations. These conditions make it hazardous to draw conclusions until the trend of these variations is known. With favorable years such as 1916 and 1917, two or three years might be sufficient to get results very near the truth; but should the year 1918 in the above experiment be added, the conclusions both relatively and quantitatively would be erroneous when compared with the average over the longer period.

FLUCTUATIONS WITH SEVERE CROPPING.

With the unfavorable climatic conditions encountered when farming without irrigation in arid regions, the yields often vary from almost nothing in dry years to 30 or 40 bushels of wheat to the acre in favorable years. Table 4 shows the variations in yield of unirrigated wheat when continuously cropped, when cropped every other year, and when cropped one year in three. More moisture is available to the crops under the latter two cropping systems than with continuous cropping.

TABLE 4.—*Percentage variation from the 11-year average yield of wheat on unirrigated plats continuously cropped, cropped during alternate years only, and cropped one year in three on the Nephi Experimental Dry Farm.*

Year.	Variation from average yield of wheat when cropped		
	Continuously.	In alternate years.	One year in three.
1909	42	−87	−83
1910	−24	−49	−75
1911	−45	44	34
1912	−42	−75	−47
1913	−56	−91	−45
1914	133	111	120
1915	24	92	90
1916	−20	−21	8
1917	60	61	24
1918	11	5	−15
1919	−81	12	5
Average variation	49	59	50
Average yield (bu.)	10.3	19.4	20.2

It will be noted that the first five years run somewhat contrary to expectations with regard to variations from the average, the continuous cropping varying independent of the other two treatments in 1909 and 1911. The conditions in 1909 were abnormally favorable for the plat cropped continuously, while they were exceptionally unfavorable for the other two plats. The spring rainfall was very low during 1911, so that the continuously cropped plat suffered, while those which had been fallowed the previous year held enough stored moisture to produce crops better than during average years. The same is true of the year 1919.

Conclusions drawn from the yields during the first five years are proportionately too favorable for continuous cropping and cropping one year in three. Results from this period also show yields much below what now appears to be the average yield.

English-speaking farmers in 1843 by Prof. J. F. W. Johnston (6). It consisted of storing green grass, clover, or vetches in pits 12 feet square and 12 feet deep. Salt at the rate of 1 pound to each hundredweight of green grass was added and the material was thoroly tramped by five or six men. After the pit was filled it was covered with boards and on these was placed a foot and a half of earth. Each pit held about 5 tons of fresh grass. It was found later that salting was unnecessary.

The similarity in the methods of making sauerkraut and silage has frequently led to the suggestion that ensiling green forages was the direct application of that well-known method of preserving cabbage. There is some basis for the belief. Sauerkraut-making was an older process than ensiling, judging from available historical data, and was commonly practiced in the countries where the method of making sour hay originated. Murray's New English Dictionary, defining the word sauerkraut, gives the following quotation under date of 1633 from Hart's Diet of the Diseased:

> They pickle it (cabbage) up in all high Germany with salt and barberies and so keepe it all the yeere, being commonly the first dish you have served in at table which they call their sawerkraut.

The fact that the Germans first used salt in making their sour hay also lends strength to this suggestion.

The method of making sour fodder was described by a correspondent to the American Agriculturist (1) in 1873 from Albrechtsfeld, Hungary. Instead of using pits, it was customary there to dig trenches 12 feet wide at the top, 6 feet wide at the bottom, 12 feet deep, and 10 to 20 rods long. The process of filling and covering was similar to that described above. He stated that sour fodder could be stored for a few years without injury. Neither of these descriptions seems to have created much interest in the subject at the time it was published. Some French farmers tried the method, but for the same cause which resulted in the failure of the first underground grain pits in France, water seepage, the practice was abandoned.

The first recorded attempt to ensile green maize was made in 1861 by Herr Adolph Reihlen (15), a sugar manufacturer, near Stuttgardt, Germany. Herr Reihlen had previously traveled in America and had taken back seed of maize which he was growing largely for soiling purposes. He was undoubtedly familiar with the German method of making sour hay and had adapted the method to the storing of beet tops and beet pulp, both of which are easily preserved as silage. As early frosts often killed the maize crop, Herr Reihlen tried storing it

in trenches. He was so well pleased with the experiment that he gave his experience in a letter dated April, 1862, which was published in the Würtemberg Wochenblatt. This was followed by another letter by the same gentleman dated September 23, 1865, and published in the same paper. These letters were translated into French by M. Vilmorin-Andrieux and published in 1870 in the Journal d'Agriculture Pratique. At the time M. Vilmorin-Andrieux prepared his report Herr Reihlen had increased his acreage of maize until he filled silos 15 feet wide at the top and slightly narrower at the bottom, 10 feet deep, and with an aggregate length of over three-fourths of a mile.

It is also of historic interest to note that Count Roederer of Bois-Roussel in the Department of the Orne in 1867 began to preserve chopped green maize mixed with cut straw in silos (5, p. 136). This method was described in a letter dated June 18, 1870, published in the Journal d'Agriculture Progressive, the following week. The purpose of this experiment was to render the straw palatable as well as to preserve the green maize. M. Piret, farm manager for A. Houette at Bleneau, Belgium, in 1868 successfully experimented with the ensiling of chopped maize. He constructed in 1870 two pits of masonry. "They were found equally serviceable to those below ground" (12).

The publication of these articles in the French agricultural press in 1870, together with a disastrous drouth which prevailed that year thruout France and ruined the hay crop, caused widespread interest to be taken in the subject. M. Moreul of La Grignonniere in 1870 built an aboveground silo of masonry and filled it with unchopped but salted maize (9). His success induced M. Crevat in 1872 to construct three pit silos 26 feet by 10 feet at the top, 22 feet by 6.5 feet at the bottom, and 6.5 feet deep. A number of other attempts were made to ensile forage besides these, which are here mentioned. Reports of experiences with this process kept appearing from time to time in the agricultural press. Another drouth in 1874 brought this subject prominently before the French farmers. The French Agricultural Society offered a prize that year to be awarded in 1876 for the best essay on the subject, "Preserving Green Forage." This action resulted in a great many literary efforts on the part of those who had tried the ensiling method. M. Goffart (3), a gentleman farmer of Burtin in Sologne, was one of the ablest of these writers. He had had considerable experience with the German system of making "brown hay" and had grown maize for forage for a number of years. He built four silos in 1852 hollowed out of the ground and

plastered with Portland cement. He did not claim success for his method, however, until 1873. His earliest silos were too small to be practicable, each holding only about 2 cubic yards. They were used to store cut and mixed straw and maize for immediate feeding. They prolonged his period of feeding green corn fodder three or four weeks but did not effectually preserve the fodder. Goffart states:

> In 1873, I had a real success, due mainly to accident. . . . Until this time I had hardly believed that the preservation of green maize for a long time was possible and I had very little confidence.

As Goffart had at that time the benefit of the successful experience of Herr Reihlen, Count Roederer, M. Piret, and M. Moreul in preserving green maize, he can hardly be credited with being the originator of the process. His comprehensive experiments, his useful writings, and his frequent lectures before agricultural societies, however, well earned the decoration of Legion of Honor which he received in 1876 and the popular esteem in which he has been held in America as the "Father of Ensilage."

THE SILO IN AMERICA.

The introduction of the silo in America was due directly to the publicity given the subject in France.

The first appearance of a description of the French process of preserving green forage appears to have been in a series of letters from a French correspondent to the American Farmer published in Baltimore, Md. These letters were dated Paris and signed F. C. They ran through a number of years. This correspondent referred to the matter in a letter in the issue of October, 1874. In the January, 1875, issue he wrote:

> Quite a revolution is taking place in the agriculture of the south of France by the cultivation of maize for green fodder and its preservation in a green state chopped and mixed with straw in trenches for winter consumption.

The subject was referred to again in subsequent letters. It was these accounts which induced Francis Morris, of Oakland Manor, Md., to try the method in 1876 (10).

In the American Agriculturist of June, 1875, was an illustrated article entitled "Curing Green Fodder" which was translated from the Journal d'Agriculture Pratique. The terms silo was used in this article, probably for the first time in an English publication. In England the terms trenching, pitting, and potting were used. The experiences of M. Piret and M. Goffart were given. Practically

everything connected with the French method was given in this article. This information was restated many times during the next five years. A more complete résumé of the subject was published in 1876 in the Annual Report of the United States Commissioner of Agriculture for 1875 (15). This was similar to the article in the American Agriculturist, being copied from the same French journal.

The Cultivator and Country Gentleman in its issue of October 21, 1875, had a communication signed B. F. J. (probably B. F. Johnson), Champaign County, Ill., from which is quoted the following:

> Prof. Miles of the Illinois Industrial University has made pretty liberal experiments in the ensilage of maize and broom corn seed in the course of this autumn, the outcome of which will be given to the public as soon as the success or want of it in the undertaking has been determined. . . . To ensilage is to bury in silo or pits.

This communication is of special interest not only because it records the first American effort to preserve green corn but it also introduces the word "ensilage" into our language. Prof. Manly Miles in the issue of October 5, 1876, of the same paper gave a summary of the experiences of farmers in Europe with the process of ensiling and also of the results of his own experiments. The following is quoted from this letter:

> Last season at Champaign, Ill., experiments on a small scale were made under my direction in the ensilage of corn stalks and broom corn seed with results that were on the whole satisfactory. Two pits 12 feet long, 6 feet wide, and about 8 inches below the surface of the soil were filled with cut corn stalks of a late variety and the piles carried up as high as the stalks could readily be made to keep their place. A covering of straw about 4 inches thick was then put over the pile and about 6 to 8 inches of earth added. After two or three weeks when the pile had settled an additional layer of earth about 8 inches in thickness was added. The stalks were cut by hand with a very inferior straw cutter.

Professor Miles went on to state that one of the pits of corn stalks was opened in December and that there was a layer of rotted material about 3 inches thick. The second pit was opened March 13, 1876, and considerably more had decayed. Below this decayed layer the silage had kept perfectly. Similar results were obtained in the case of the broom corn seed. Professor Miles suggested that the term ensilage be adopted to designate the method as there was no English equivalent.

Francis Morris, of Oakland Manor, near Ellicott City, Maryland, built a silo in 1876 and filled it with corn. This silo was a trench 4 feet wide, 10 feet deep, and 24 feet long. Mr. Morris became a very

enthusiastic advocate of the silo and his experiences were given in a number of farm papers. Mr. J. B. Brown, of New York, translated the book "Ensilage of Maize" of A. Goffart. This was published in 1879 and distributed largely as an advertisement of an implement company of which Mr. Brown was president. This little book created a great deal of interest and Goffart was heralded as the "Father of Ensilage." From that time until the present, books, bulletins, and articles in the agricultural press on the subject "silos and silage"—much of it controversial—have appeared so frequently that the literature is too voluminous to need special enumeration. For the first 20 years after its introduction, silo-building was a haphazard proposition. Each farmer tried his own individual ideas. Some of these were good, others were costly experiences to the builders. On the whole many valuable data were gained during this experimental stage. It was soon found that with air-tight walls all of the spoiled silage was at the top. This led to building the silos above ground and taller. With the taller silos weighting on the top of the silage was unnecessary. There was also a big saving in labor of tramping the cut material at filling time.

In 1891, Prof. F. H. King, of the Wisconsin Agricultural Experiment Station, began a study of the whole subject of silo construction and ensiling. This study covered a number of years in which he personally inspected over 200 silos. He was aided by quite a mass of data which had been collected at other experiment stations. The publication of Professor King's researches marked a new era in silo construction (7, 8). A few cylindrical silos had been constructed before that time, but King's description of the details of construction were so clear that the Wisconsin silo became for a decade the most popular type built. The pits, trenches, and low, squatty, rectangular structures gave way to the tall, cylindrical silos. The Wisconsin silo is no longer practicable owing to the comparative high cost of construction and early decay. But the principles of construction, the weights and lateral pressure of silage at different depths, and the size of silo to build for a given number of animals as worked out by King and published in several reports and bulletins of the Wisconsin Agricultural Experiment Station are used more today than when they were first written. King's silage tables are classics. No man has done more than he to make the silo a success.

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12. Curing green fodder. *In* Amer. Agr., v. 34, no. 6, p. 222. 1875.
13. ——. *In* Amer. Farmer, v. 4, no. 6, p. 250. 1875.
14. Purchas his Pilgrimes, a Relation of Plymouth, v. 19, p. 320. Glasgow, 1889.
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AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the April JOURNAL was 531. Since then, seven new members have been added, making the present membership 538. The names and addresses of the new members, with the changes of address which have been noted by the secretary and editor, are as follows:

NEW MEMBERS.

ANDERSON, HAROLD, 610 Keyser Bldg., Baltimore, Md.
CHRISTENSEN, FRED G., Box 785, Kingsbury, Cal.
DE YOUNG, WILLIAM, Soils Dept., Univ. of Mo., Columbia, Mo.
OGAARD, A. J., College of Agriculture, Bozeman, Mont
QUA, N. C., School of Agriculture, Vermilion, Alta., Canada.
SINGLETON, H. P., Washington State College, Pullman, Wash.
SUMNER, HERBERT R., College of Agriculture, Bozeman, Mont.

CHANGES OF ADDRESS.

BANCROFT, ROSS L., Phillips, Wis.
CUNNINGHAM, C. C., R. F. D. No. 4, Edwards, Kans.
SCHUSTER, GEO. L., Experiment Station, Newark, Del.

NOTES AND NEWS.

L. R. Breithaupt, formerly superintendent of the Harney County Branch Station, Burns, Oreg., and more recently engaged in farming in Idaho, is now county agricultural agent of Malheur County, Oreg.

T. S. Buie, assistant agronomist at the Georgia station, has been made head of the department of agronomy.

W. L. Burlison, for the past several years professor of crop production in the University of Illinois, has been made head of the department of agronomy, filling the vacancy caused by the death of Dr. C. G. Hopkins.

J. B. R. Dickey, formerly extension specialist in agronomy and soils in Rutgers College, is now assistant professor of agronomy extension in the Pennsylvania college.

J. A. Evans, for the past several years connected with the Federal Office of Extension Work in the South, has been appointed to succeed Bradford Knapp at the head of that office.

Sidney B. Haskell, head of the department of agronomy at the Massachusetts college and station from 1911 to 1916 and since connected with the Soil Improvement Committee of the National Fertilizer Association, has been elected director of the Massachusetts station, effective July 1.

R. R. Hudelson, assistant professor of soils, and E. M. McDonald, assistant professor of farm crops in the University of Missouri, have resigned to engage in farming in Alberta.

James T. Jardine, for the past several years in charge of grazing experiments in the Forest Service, has been elected director of the Oregon station, effective June 1.

Harry L. Kent, director of agricultural education in Kansas under the Smith-Hughes act and principal of the school of agriculture at the Kansas College, has been elected head of the Fort Hays Branch Station, Hays, Kans., effective May 15.

J. D. Luckett, formerly specialist in field crops on the Experiment Station Record, is now editor and librarian of the New York State station.

George L. Schuster, formerly assistant agronomist at the University of West Virginia, has been agronomist of the Delaware college and station since April 1.

John A. Slipher, formerly of the department of soil technology at Purdue University, is now assistant manager of the agricultural department of the National Lime Association.

S. H. Starr, formerly assistant professor of farm management at the Georgia college, is now director of the newly established Georgia Coastal Plains station at Tifton, which is entirely distinct from both the Georgia college and station.

E. D. Stewart, superintendent of the Langdon (N. Dak.) experiment farm and recently appointed superintendent of farm demonstrations in North Dakota, died of influenza March 12.

Theodore Stoa, formerly scientific assistant in the Federal office of cereal investigations, is now assistant agronomist at the North Dakota station.

John H. Voorhees, assistant agronomist in extension at Cornell University, resigned February 1 to become associate editor of the *Pennsylvania Farmer*.

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THE INEQUALITY OF RECIPROCAL CORN CROSSES.[1]

Frederick D. Richey.

Introduction.

Although reciprocal crosses are in general practically indistinguishable, there are well recognized exceptions to this rule. For example, reciprocal crosses between *Digitalis purpurea* and *D. lutea* constantly produce hybrids that resemble the female parent, whereas reciprocal crosses between *Oenothera biennis* and *O. muricata* give hybrids that strongly resemble the male parent. Reciprocal crosses between varieties or strains of corn (*Zea mays* L.) have been compared by several investigators and different results obtained.

Shull (13)[2] concluded from the results of his investigations that "The reciprocals between two distinct, self-fertilized families are equal," and East and Hayes (4) note the agreement of their results with those of Shull. Burtt-Davy (2) states with reference to the crosses between breeds with 8 and 18 rows, "The ears produced by the cross and the reciprocal cross are indistinguishable," and (3) observes in general, "It appears to be immaterial which breed furnishes the male and which the female parent; the results in the F_2 generation are usually the same in either case." Williams and Welton (15) note without comment the equality of two reciprocal crosses, both in yield and in moisture content. As to the inheritance of individual qualitative factors, it seems sufficient to say that no report has

[1] Contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Publication approved by the Secretary of Agriculture. Received for publication April 22, 1920.

[2] Reference is by number to "Literature cited," p. 195.

been found of inequality in germinal inheritance between reciprocal crosses.

On the other hand, however, McCluer (12) noted that the cross, Queen Golden × White Dent, resembled the dent parent, whereas the reciprocal cross was intermediate. Gernert (5) states that differences between reciprocals were observed both as to plant and seed characters, and more specifically notes differences of four to eight days in the period from planting to silking. Jones (7) concludes, "Although reciprocal crosses are on the whole nearly equal in respect to the degree in which heterosis is shown, there is some evidence from Table 12 that this is not always so." Jones' conclusion is of particular interest, as he used later generations of some of the inbred strains used by East and Hayes (4) in their investigations. Jones notes a correlation between better seed development in certain strains and larger yields from the crosses having these strains for pistillate parents, and is inclined to attribute the differences between the reciprocals to the difference in the food materials furnished the young plants. He notes, however, "It is not certain that these differences can be accounted for on a purely nutritional basis," and suggests the "possibility of unequal germinal reactions with different cytoplasms." Jones (7, Table 17, p. 51) also gives data which show inequality between reciprocals in each of two pairs of reciprocal crosses between different types of corn.

The present paper compares the yields of three pairs of reciprocal crosses between commercial varieties of corn, and shows inequality in each pair. Data also are presented which show that in one pair of these reciprocals the inequality is caused by the inheritance of some character from one of the parent varieties only when that variety is used as the staminate parent.

Comparison of Reciprocals.

VARIETIES AND METHODS.

The following varieties of corn were used as parents of the reciprocal crosses discussed:

U. S. Selection No. 119, a strain of Boone County White, grown near Washington, D. C., since 1902.

U. S. Selection No. 120, a cross of Hickory King × No. 119, grown near Washington, D. C., since 1902.

U. S. Selection No. 199, Fraley Yellow Dent, grown near Derwood, Md., since 1900.

U. S. Selection 200, St. Charles White, grown near St. Charles, Mo., since 1850.

"Johnson," a mixed strain of Johnson County White, grown in northeastern Arkansas since 1912.

The crosses were made by growing rows of the varieties used as pistillate parents between rows of the varieties used as staminate parents, and detasselling the former rows before they had shed pollen. From 15 to 25 ears were obtained from the detasseled rows to represent each cross.

The methods of comparison are given in connection with each experiment. In all the experiments, however, the corn was planted thick and was later thinned to the desired stand. All yields were corrected to a basis of air-dry shelled corn.

RECIPROCAL CROSSES BETWEEN U. S. SELECTION NOS. 120 AND 199.

These crosses were compared at Gaithersburg, Md., and at Occoquan, Va., in 1912.[3] Each cross was grown in a row between rows of the parent varieties, and intra-hill with each parent variety. The reciprocals therefore can be compared thru the ratios of their respective yields to the average yield of the parent varieties. This comparison is made in Table 1, the yield per plant being given for reference.

TABLE 1.—*Comparison of the reciprocal crosses between U. S. Selection Nos. 199 and 120.*[a]

Locality and method of planting.	Replication No.	120 × 199. Yield per plant. Average of parents.	Cross.	Ratio of cross to parents.	199 × 120. Yield per plant. Average of parents	Cross.	Ratio of cross to parents.	120 × 199 exceeds its reciprocal.
		Pounds.	*Pounds.*	*Percent.*	*Pounds.*	*Pounds.*	*Percent.*	*Percent.*[b]
Gaithersburg:								
Inter-row..	1	0.631	0.681	107.9	0.462	0.461	99.8	8.1
	2	.615	.692	112.5	.532	.530	99.8	12.7
	Ave.	.623	.687	110.3	.497	.496	99.8	10.5
Intra-hill..	1	.613	.676	110.3	.494	.443	89.7	23.0
	2	.664	.698	105.1	.538	.519	96.5	8.9
	Ave.	.639	.687	107.5	.516	.481	93.2	15.3
Occoquan:								
Inter-row..	1	.595	.567	95.5	.578	.527	91.2	4.5
	2	.473	.451	95.3	.507	.517	102.0	−6.6
	Ave.	.534	.509	95.4	.543	.522	96.1	−0.7
Intra-hill..	1	.566	.579	102.3	.493	.522	105.9	−3.4
	2	.435	.440	101.1	.487	.542	111.3	−9.2
	Ave.	.501	.510	101.8	.490	.532	108.6	−6.3

[a] All averages are calculated directly from basic yield figures.

[b] Percent of 199 × 120, in terms of the average of the parents.

[3] These crosses were grown in connection with experiments to determine the relative productiveness of F_1 crosses and their parent varieties. These experiments were planned and carried out in 1911–1912 by the Office of Corn Investigations, U. S. Department of Agriculture. The methods used in these experiments are given more fully in a later part of this paper.

The results show that No. 120 × No. 199 was markedly superior to its reciprocal at Gaithersburg, whereas at Occoquan it was slightly inferior to its reciprocal.

EXPERIMENTS IN 1915–1917.

The experiments from 1915 to 1917 were conducted at Armorel, Ark. Crosses were made between U. S. Selection Nos. 119 and 120 in 1915. Two sets of ears were used to represent each variety, and each set was used as a staminate and as a pistillate parent. Sixteen combinations were thus obtained; four to each parent and cross. Each of these 16 combinations was grown in 1916 in a 2-row plat between 1-row check plats. The actual yields of the experimental plats were corrected by the formula, $(a+b)/(c'+c'')\times C$, in which a and b are the yields of the two rows of an experimental plat, c' and c'' are the yields of the check plats on each side of a and b, and C is the average of all the checks. The four combinations that represented each variety or cross are treated as replications. The same methods were used to make and compare the crosses between Johnson and U. S. Selection No. 200 in 1916–17. The results of these experiments are shown in Table 2.

TABLE 2.—*Comparison of reciprocal crosses between U. S. Selection Nos. 119 and 120, and between Johnson and U. S. Selection No. 200, in bushels of shelled corn per acre.*

NO. 119 × NO. 120.

Strain.	Yield in bushels per acre.					No. of plants.
	Replication No.				Average.	
	1	2	3	4		
No. 120	35.0	34.6	31.4	31.0	33.0±0.7	1,087
120 × 119	40.0	39.9	39.2	38.1	39.3± .3	1,107
119 × 120	35.9	35.5	34.5	33.7	34.9± .3	1,104
No. 119	32.9	27.1	31.3	28.5	30.0± .9	1,116

JOHNSON × NO. 200.

Strain.	1	2	3	4	Average.	No. of plants.
Johnson	61.5	60.9	56.7	59.1	59.6±0.7	1,392
Johnson × 200	69.1	66.8	67.4	68.1	67.9± .3	1,392
200 × Johnson	64.6	67.8	63.8	65.7	65.5± .6	1,392
No. 200	66.2	63.0	61.7	61.5	63.1± .7	1,392

The cross No. 120 × No. 119 exceeds its reciprocal by 4.4 ± 0.4 bushels per acre, or 12.6 ± 1.2 per cent. The cross Johnson × No. 200 exceeds its reciprocal by 2.4 ± 0.7 bushels per acre, or 3.7 ± 1.0 per cent. The difference between the reciprocals is significant in each

case, that between No. 120 × No. 119 and No. 119 × No. 120 being especially so. In this connection it is of interest to note that No. 120 × No. 119 is the same combination that gave the maximum increase over the better parent in earlier crossing experiments (6).

CAUSE OF INEQUALITY BETWEEN RECIPROCALS.

Nutritional differences and varying germinal reactions with different cytoplasms have been suggested as possible causes of inequality between reciprocal corn crosses. Relative early vigor and productiveness of the parents is the only evidence that bears even indirectly on these points in connection with the present crosses. The use as a specific parent of the variety producing either the more vigorous early growth or the larger yield had no consistent effect in determining the better reciprocal. This is shown in Table 3.

TABLE 3.—*Relation between the better reciprocal and greater early vigor or productiveness in a specific parent.*

Better reciprocal.	Parent showing more vigorous early growth.	Parent producing greater yield.
No. 120 × No. 119	Pistillate	Pistillate
Johnson × No. 200	Staminate	Staminate
No. 120 × No. 199[a]	Neither	Staminate[a]

[a] At Gaithersburg.

The possibility of sex linkage as a cause of inequality between the reciprocals of Nos. 120 and 199 is interesting in the light of the following experiments. Two series of crosses were made in 1911,[4] No. 120 being used as the staminate parent of one series at Vienna, Va., and No. 199 of the other at Derwood, Md. Twenty varieties, including Nos. 120 and 199, were used as pistillate parents and seed of the following classes thus obtained: Nos. 120 and 199 from detasseled plants; the reciprocal crosses between Nos. 120 and 199; and 18 varieties × No. 120 and × No. 199. These, together with the pistillate parent varieties, were compared at Gaithersburg, Md., and Occoquan, Va., in 1912. The arrangement was the same at both places. Each cross was grown with its parents in a group of six rows in the following order:

1. Staminate parent.
2. Cross.
3. Pistillate parent.
4. Cross and staminate parent.
5. Cross and pistillate parent.
6. Pistillate parent and staminate parent.

[4] See footnote 3.

In the first three of these rows comparisons are based on row yields and are referred to as "inter-row." In the last three rows the two classes that were grown in different sides of the hills of the same row are compared and these comparisons are referred to as "intra-hill" (10, 11). Each row contained 60 2-plant hills and was duplicated. For convenience, the 18 varieties × 120, the 18 varieties × 199, and the 18 pistillate parent varieties will be referred to as the 120-crosses, the 199-crosses, and the 18 varieties, respectively.

The 120-crosses were compared with their respective parents in a plat of 18 consecutive groups. No. 120 occupied row 1 of each of these groups, one of the 120 crosses occupied row 2 of each group, and one of the 18 varieties occupied row 3 of each group. The relative average yield of No. 120 and of the 120-crosses therefore can be computed as percentages of the average yield of the 18 varieties as illustrated in the formula,

$$\frac{1^1 + 1^2 + 1^3 + \cdots + 1^{18}}{3^1 + 3^2 + 3^3 + \cdots + 3^{18}} = \text{Relative average yield of No. 120},$$

in which the terms in the numerator represent the yields of rows of No. 120 in successive groups, and those in the denominator represent

TABLE 4.—*Comparison of 199-crosses and 120-crosses thru their ratios to 18 varieties.*[a]

Locality and method of planting.	Replication No.	199-crosses. Yield per plant. Varieties.	199-crosses. Yield per plant. Crosses.	199-crosses. Ratio of crosses to varieties.	120-crosses. Yield per plant. Varieties.	120-crosses. Yield per plant. Crosses.	120-crosses. Ratio of crosses to varieties	199-crosses exceed 120-crosses.
		Pounds.	*Pounds.*	*Percent.*	*Pounds.*	*Pounds.*	*Percent.*	*Percent.*[b]
Gaithersburg:								
Inter-row	1	0.511	0.592	115.9	0.466	0.499	107.1	8.2
	2	.536	.618	115.3	.521	.543	104.2	10.7
	Ave.	.524	.606	115.6	.494	.521	105.5	9.6
Intra-hill	1	.511	.579	113.3	.487	.486	99.8	13.5
	2	.534	.593	111.0	.544	.527	96.9	14.6
	Ave.	.523	.586	112.0	.516	.507	98.3	13.9
Occoquan:								
Inter-row	1	.467	.495	106.0	.495	.512	103.4	2.5
	2	.452	.476	105.3	.538	.544	101.1	4.2
	Ave.	.460	.485	105.4	.517	.528	102.1	3.2
Intra-hill	1	.483	.513	106.2	.511	.532	104.1	2.0
	2	.452	.480	106.2	.534	.548	102.6	3.5
	Ave.	.467	.496	106.2	.523	.540	103.2	2.9

[a] All averages are calculated directly from basic yield figures.
[b] Percent of the 18 varieties × No. 120, in terms of the 18 varieties.

the yields of the 18 varieties in the same groups. The 199-crosses were grown in a similar plat of 18 groups and the relative average

yield of No. 199 and the 199-crosses can also be computed as percentages of the average yield of the 18 varieties. Under the inter-row method, No. 120 and the 120-crosses then can be compared with No. 199 and the 199-crosses thru their relative yields.

Similarly under the intra-hill method, Nos. 120 and 199 can be compared thru the relation of their yields to the yield of 18 varieties grown intra-hill with them in row 6 of each group; and the 120-crosses can be compared with the 199-crosses thru their relative yields in row 5 of each group. Table 4 shows the comparison of the crosses and Table 5 the comparison of Nos. 120 and 199. The actual yields in pounds of air-dry shelled grain per plant are shown for reference.

At Gaithersburg No. 199 exceeded No. 120 by 14.7 percent, when grown inter-row, and by 28.7 percent, when grown intra-hill. At Occoquan the differences were negligible, being but 2.1 percent and 0.6 percent.

TABLE 5.—*Comparison of Nos. 199 and 120, thru their ratios to 18 varieties.*[a]

Locality and method of planting.	Replication No.	No. 199.			No. 120.			No. 199 exceeds No. 120.
		Yield per plant.		Ratio of No 199 to 18 varieties.	Yield per plant.		Ratio of No. 120 to 18 varieties.	
		Average of 18 varities.	No 199.		Average of 18 varieties.	No. 120		
		Pounds.	*Pounds.*	*Percent.*	*Pounds.*	*Pounds.*	*Percent.*	*Percent.*[b]
Gaithersburg:								
Inter-row..	1	0.511	0.611	119.6	0.466	0.492	105.6	13.3
	2	.536	.628	117.2	.521	.525	100.8	16.3
	Ave.	.524	.619	118.1	.494	.509	103.0	14.7
Intra-hill..	1	.487	.630	129.4	.501	.490	97.8	32.3
	2	.531	.650	122.4	.539	.526	97.6	25.4
	Ave.	.509	.640	125.7	.520	.508	97.7	28.7
Occoquan:								
Inter-row..	1	.467	.504	107.9	.495	.522	105.5	2.3
	2	.452	.469	103.8	.538	.551	102.4	1.4
	Ave.	.460	.487	105.9	.517	.536	103.7	2.1
Intra-hill .	1	.493	.487	98.8	.508	.512	100.8	−2.0
	2	.448	.459	102.5	.542	.537	99.3	3.2
	Ave.	.471	.473	100.4	.525	.524	99.8	0.6

[a] All averages are calculated directly from the basic yield figures.
[b] Percentage of No. 120 in terms of the 18 varieties.

At Gaithersburg the 199-crosses exceeded the 120-crosses by 9.6 percent, when grown inter-row, and by 13.9 percent, when grown intra-hill. At Occoquan, on the other hand, the 199-crosses exceeded the 120-crosses by only 3.2 percent, inter-row, and 2.9 percent, intra-hill.

This method of comparison thru relative yields differs from the

ordinary method of checking for environmental variation only in the use of 18 varieties as the standard instead of one variety. The use of a number of varieties seems preferable, for the average yield of a number of varieties will be less influenced by specific adaptation and therefore will represent better the potential productiveness of the environment.

Nos. 120 and 199 also were compared in six pairs of adjacent rows, and intra-hill in six rows at Gaithersburg and at Occoquan. The direct comparison between the yields of No. 120 and No. 199 in these rows is made in Table 6. This agrees in general so closely with the comparison thru relative yields (Table 5) as to demonstrate the reliability of the latter method.

TABLE 6.—*Comparison of Nos. 120 and 199, based on actual yields in pounds of air-dry shelled corn per plant in adjacent rows and intra-hill.*

GAITHERSBURG.

Comparison No.	Inter-row.			Intra-hill.		
	No. 199.	No. 120.	No. 199 exceeds No. 120.	No. 199.	No. 120.	No. 199 exceeds No. 120.
1	0.467	0.457	0.010	0.732	0.594	0.138
2	.568	.494	.074	.724	.620	.104
3	.681	.580	.101	.570	.418	.152
4	.671	.558	.113	.602	.458	.144
5	.646	.561	.085	.714	.530	.184
6	.654	.572	.082	.680	.574	.106
Average	0.615	0.537	0.078 ± .010	0.670	0.532	0.136 ± .008

OCCOQUAN.

Comparison No.	No. 199.	No. 120.	No. 199 exceeds No. 120.	No. 199.	No. 120.	No. 199 exceeds No. 120.
1	0.575	0.581	−0.006	0.592	0.492	0.100
2	.490	.524	− .034	.392	.430	− .038
3	.643	.547	.096	.544	.526	.018
4	.473	.472	.001	.528	.534	− .006
5	.566	.594	− .028	.648	.534	.114
6	.590	.561	.029	.662	.598	.064
Average	0.556	0.547	0.010 ± .013	0.561	0.519	0.042 ± .017

No. 199 exceeded No. 120 by 0.078 ± 0.10 bushel, or 14.5 ± 1.9 percent, at Gaithersburg when grown inter-row, and by 0.136 ± .008 bushel, or 25.6 ± 1.5 percent, when grown intra-hill. At Occoquan, it exceeded No. 120 by .010 ± .013 bushel, or 1.8 ± 2.4 percent, when grown inter-row, and by 0.042 ± .017 bushel, or 8.1 ± 3.3 percent, when grown intra-hill.

The effect of greater competition in the intra-hill method reported by Kiesselbach (10) as a source of error in varietal experiments is

clearly shown in these results. This effect serves to strengthen the conclusiveness of the present results, however, as the intensification is entirely consistent with the results obtained under both methods.

These experiments show conclusively that No. 199 was superior to No. 120 (Tables 5 and 6) and that the 199-crosses were superior to the 120-crosses (Table 4) at Gaithersburg. At Occoquan the differences were insignificant. That No. 120 × No. 199 was better than

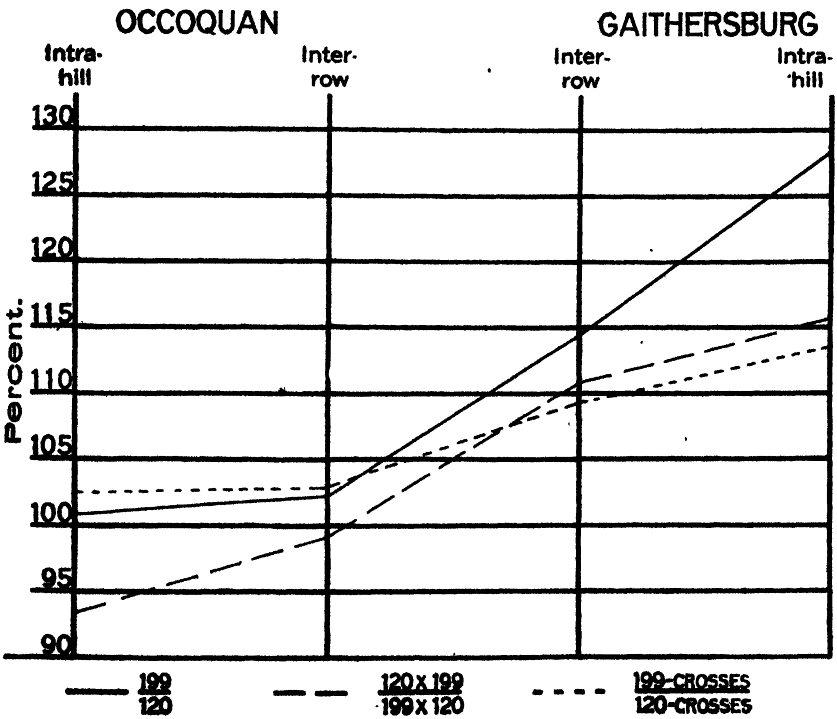

FIG. 14. Graph showing the ratios of No. 199 to No. 120, No. 120 × No. 199 to No. 199 × No. 120, and the 199-crosses to the 120-crosses, at Occoquan and Gaithersburg.

No. 199 × No. 120 at Gaithersburg and not so good at Occoquan has been shown in Table 1. This similarity in the relative behavior of the series that had No. 199 for staminate parent in comparison with the series that had No. 120 for staminate parent is brought out more clearly in Table 7, which summarizes Tables 1, 4, 5, and 6, and in figure 14, which shows the relation graphically.

These two series differed thruout in only one way other than parentage, namely, the conditions under which the seed was grown.

TABLE 7.—*Superiority of No. 120 × No. 199, the 199-crosses, and No. 199, over No. 199 × No. 120, the 120-crosses, and No. 120, respectively.* (Summary of Tables 1, 4, 5, and 6.)

Superiority of:	Table No.	Gaithersburg.		Occoquan.	
		Inter-row.	Intra-hill.	Inter-row.	Intra-hill.
		Percent.	*Percent.*	*Percent.*	*Percent.*
120 × 199	1	10.5	15.3	−0.7	−6.3
199-crosses	4	9.6	13.9	3.2	2.9
199 (relative)	5	14.7	28.7	2.1	0.6
199 (actual)	6	14.5±1.9	25.6±1.5	1.8±2.4	8.1±3.3

The seed of No. 120 and the crosses of which it was the staminate parent was grown at Vienna, Va., and seed of No. 199 and the crosses of which it was the staminate parent at Derwood, Md. These places are about 20 miles apart, the soils and seasons are similar in general, and there was no apparent difference in the quality of the seeds as is seen from Table 8.

TABLE 8.—*Notes on seed grown at Vienna, Va., and Derwood, Md., in 1911, based on the average of 19 crosses and the staminate parent.*

Locality.	Staminate parent.	Seed condition.[a]	Germination.	Weight of struck 2 quarts
		Percent.	*Percent.*	*Pounds.*
Vienna, Va.	No. 120	79.8	98.95	3.32
Derwood, Md.	No. 199	81.5	98.65	3.28

[a] Seed condition represents the judgment of the observer.

From the data in Table 8 there is nothing to indicate that the differences in yield were caused by the difference in the conditions under which the seed was grown. Moreover, under both the inter-row and the intra-hill methods and in the difference between the methods, the 199-crosses show this suitability to Gaithersburg conditions less than does No. 199. This indicates an intermediate condition and genetic causes rather than physiological ones.

The only logical interpretation of the above facts and one which follows them so closely that it is essentially equivalent to restating them is; that No. 199 possessed some character that particularly suited it to the Gaithersburg environment. No. 120 did not possess this character, nor did the 18 varieties as a whole. This character was transmitted, in part at least, to the 199-crosses and to No. 120 × No. 199, in each of which No. 199 was the staminate parent. This character was transmitted slightly, if at all, to No. 199 × No. 120, in which No. 199 was the pistillate parent. There was, therefore, a dif-

ference in transmission from No. 199 when it was used as the staminate and the pistillate parent, respectively.

Unfortunately, this is as far as the facts go and any attempt to explain the exact method of this unequal transmission must be speculative. However, the results follow the operation of sex-linked inheritance so closely that we are led to consider the possibility of some type of sex linkage as a cause of inequality between reciprocal corn crosses. That sex-linked inheritance of specific qualitative characters has not been observed in corn is relatively unimportant; for nine of the factors more thoroly investigated already have been placed in but three groups (8, 9), whereas the number of chromosomes in corn is large. That sex linkage may occur in corn does not seem impossible in view of its occurrence in Lychnis (13) and in Begonia (1).

Conclusion.

The reciprocal crosses between varieties or strains of corn sometimes are unequal. A difference in the food materials furnished the young plants by the different maternal parents and a difference in germinal reactions with different cytoplasms have been suggested as possible causes of such inequalities. That some type of sex-linked inheritance must at least be considered as a possible cause of inequality between rciprocal corn crosses is shown by the unequal transmission from No. 199 as staminate and as pistillate parent in the above experiments.

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RELATIVE YIELDS FROM BROKEN AND ENTIRE KERNELS OF SEED CORN.[1]

ERNEST B. BROWN.

It is not uncommon to find kernels in seed corn that have been physically injured. These injuries are usually the result of weevil attacks, gnawing by mice, cracking in shelling and seeding, or abrasions from other causes. Ordinarily, the presence of a small percentage of injured kernels is not regarded as seriously affecting the quality of the seed. Occasionally, either from necessity or otherwise, corn containing a considerable percentage of injured kernels is planted. Whether injuries of this physical nature affect the growth, development, and productivity of the plant is the subject of this investigation.

Three ears of U. S. Selection No. 120, a white dent variety, were used in the experiment. Broken or cracked kernels from each ear were planted in comparison with uninjured kernels from the same ear. The breaking was similar to the injuries that frequently occur in mechanical shelling and seeding, and analogous to weevil and mouse damage in that the amount of nutriment in the kernel was lessened. The injuries were confined to the endosperm, in no instance extending to the germ.

The experiment was conducted on Arlington Farm, near Washington, D. C., in 1914. The corn was planted May 29 by hand in rows 3.3 feet apart, 40 hills per row, with the hills 3.3 feet apart in the row. When the plants were 6 to 8 inches tall, the stand was thinned to 2 plants per hill. The crop was harvested October 30. The statistical data are presented in Table 1.

[1] Contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication June 30, 1920.

TABLE 1.—*Comparison of yields from broken and entire kernels of seed corn, U. S. Selection No. 120.*

Row No.	Class.	Adult plants.	Ears produced.	Total weight of ears.	Ears per plant.	Average weight of ears.	Yield per plant.	Yield per acre[a].
				Pounds.		*Pounds.*	*Pounds.*	*Bushels.*
	Ear 1:							
64	Broken seed	43	52	29.1	1.210	0.560	0.677	67.7
65	Entire seed	77	76	56.6	.988	.745	.735	73.5
	Ear 2:							
66	Broken seed	66	57	38.8	.864	.681	.588	58.8
67	Entire seed	86	82	59.8	.954	.730	.696	69.6
	Ear 3:							
68	Broken seed	62	62	41.6	1.000	.671	.671	67.1
69	Entire seed	69	71	49.8	1.029	.702	.722	72.2
Averages								
	Broken seed	57	57	36.5	1.000	.640	.640	64.0
	Entire seed	78	77	55.4	.988	.716	.716	71.6
	Difference							7.6

[a] Based on 7,000 plants per acre and 70 pounds of ears to the bushel.

The field germination from the broken seed was less than from the entire seed and the seedlings were weaker.

The general height of plants at maturity did not materially differ. Apparently the mutilation of the seed was not a limiting factor in the height of the plant.

In number of ears per plant the broken seed exceeded the entire seed in one out of three comparisons and in the general average. The increase in number of ears was associated with the increased space per plant resulting from the poorer stands from broken seed.

In weight of ear and yield per plant, the yield from broken seed was consistently less than that from the entire seed.

On an acre-yield basis, the broken seed yielded 7.6 bushels less than the entire seed. In practical corn growing, the losses in yield probably would be much less, frequently negligible, but the tendency would be the same.

AN OUTLINE OF AN UNDERGRADUATE COURSE IN GRAIN GRADING.[1]

JOHN B. WENTZ.

One phase of agronomic work which has come to the attention of teachers of farm crops in the last few years is the teaching of the grading of grains according to the Federal standards established by the Grain Standards Act. As the grade requirements of the different grains have been published by the Bureau of Markets, it has been found necessary to change the system of teaching the grading of grains to conform to the requirements of the new standards. In institutions where no special attention had previously been given to market grading of grains, it has been found necessary to give consideration to this work. The use of the Federal standards in the grain markets has stimulated a desire among grain dealers and farmers to gain a knowledge of the methods of applying the standards, and this fact, together with the generally increased interest in the last few years in marketing of farm products, has greatly increased the demands made on the agricultural colleges for information on market grading of grains.

Numerous applications were addressed to the Bureau of Markets by farm crops teachers asking for information and materials to be used in instructional work. These requests finally resulted in a conference of the agricultural college men interested in grain grading and representatives of the Bureau of Markets, to furnish subject matter on the Federal standards for instructional work. This conference was held at the General Field Headquarters of Federal Grain Supervision, Chicago, Ill., September 8 to 11, 1919.

In the two years previous to the conference at Chicago, the agronomy department of the Maryland State College had been collecting the apparatus and subject matter for the teaching of grain grading according to the Federal standards, and in the year previous to the conference a 2-hour course was offered to juniors in the winter term. This year the course is being offered in the same term, but the number of hours has been increased to three, including two lectures and one 3-hour laboratory period per week. The interest of the stu-

[1] Contribution from the Department of Agronomy, Maryland State College, College Park, Maryland. Received for publication April 12, 1920.

dents in this course and the amount of general interest it has contributed to the farm crops work at this institution seems to justify a report to members of other agronomy departments who might be interested in this work. Two views of the apparatus used are shown in Plate 8.

Following is an outline of the course as it is now being conducted.

OUTLINE OF COURSE IN GRAIN GRADING.

I. History leading up to the passing of the Grain Standards Act (7).[2]

II. United States Grain Standards Act (2).
- A. Date passed.
- B. Value in foreign trade.
- C. Value in interstate trade.
- D. Indirect effect upon intrastate and local trade (6).
- E. How the farmer is affected (1).
- F. Classifications and grades provided by the Federal standards.
  - 1. For wheat (3).
    - *a*. Classes, subclasses, and grades. (As shown by charts put out by the Bureau of Markets.)
    - *b*. Wheat districts (shown by map).
    - *c*. Descriptions of the six market classes of wheat (both thrashed and head samples of each class exhibited.
      - District where grown.
      - Texture.
      - Color.
      - Milling quality.
  - 2. For corn (3).
    - *a*. Classes and grades (as shown by charts).
  - 3. For oats (4).
    - *a*. Classes and grades (as shown by charts).
- G. The organization to carry out the provisions of the act.
  - 1. The licensed inspector.
    - *a*. Qualifications of the inspector.
    - *b*. Duties.
    - *c*. How he obtains his license and his relation to the Federal government (2).

[2] Reference by number is to "Literature cited," p. 203.

- *d*. Rules and regulations governing the inspector (2).

2. The district supervisor.
   - *a*. Division of United States into supervision districts (shown by map).
   - *b*. Qualifications of the supervisor.
   - *c*. Duties.
   - *d*. How to use the supervisor's office (5).
     How to take an appeal.
     How to take a dispute.
     Definition of terms used in connection with appeals and disputes.
3. The board of review.
   - *a*. Location.
   - *b*. Duties.
4. Secretary of Agriculture.
   - *a*. Relation to the inspection and grading work.
5. Relations between inspectors, supervisors, board of review, and Secretary of Agriculture. (Explained by use of diagram on blackboard.)

III. Bases upon which the grain grades are established.

In this part of the course the students are assigned references to report on and discuss before the class. The references used are listed below in about the order in which they are taken up by the class.

1. U. S. Dept. Agr. Bul. 328. Milling and baking tests of wheat containing admixtures of rye, corn cockle, kinghead, and vetch.
2. U. S. Dept. Agr., Bur. Plant Indus. Bul. 100. Garlicky wheat.
3. Ind. Agr. Expt. Sta. Bul. 176. Wild garlic and its eradication.
4. U. S. Dept. Agr. Farmers' Bul. 610. Wild onion: Methods of eradication.
5. U. S. Dept. Agr. Bul. 455. The drying for milling purposes of damp and garlicky wheat.
6. U. S. Dept. Agr. Farmers' Bul. 919. Methods of handling dockage.
7. U. S. Dept. Agr. Bul. 557. A comparison of several classes of American wheats and a consideration of some factors influencing quality.
8. Bureau of Markets Service and Regulatory Announcements 54. How hard red winter wheat is grading under Federal standards.
9. U. S. Dept. Agr. Bul. 788. Moisture in wheat and mill products.
10. U. S. Dept. Agr. Bul. 751. Experiments in the digestibility of wheat bran in a diet without wheat flour.
11. Utah Agr. Expt. Sta. Bul. 103. Milling qualities of wheat.
12. Canadian Dept. Agr. Bul. 57. Quality in wheat.
13. U. S. Dept. Agr. Bul. 48. The shrinkage of corn while in cars in transit.

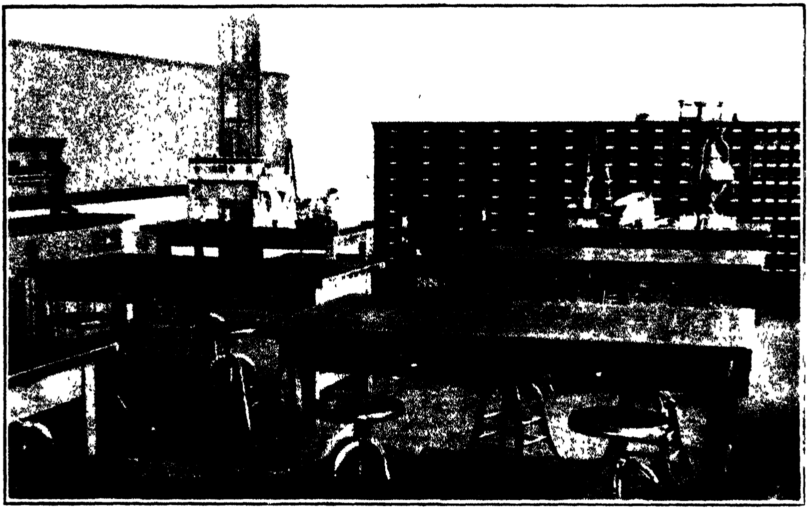

FIG. 1 View of the grain-grading laboratory at Maryland State College

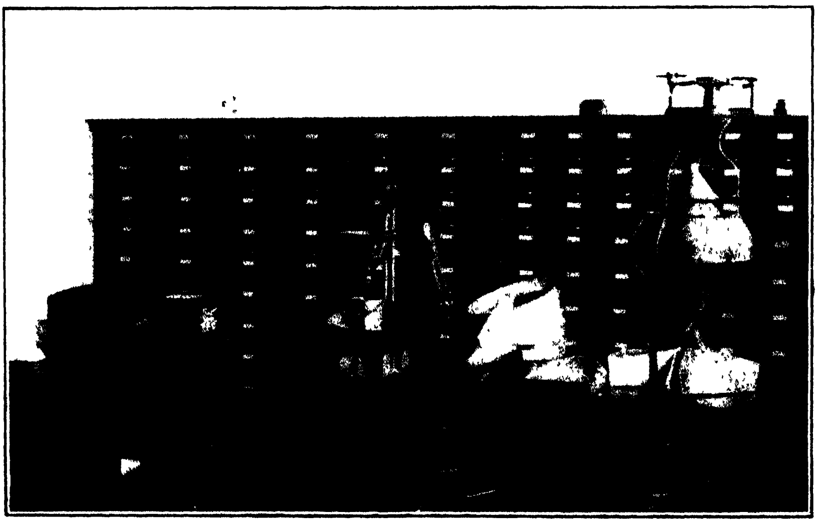

FIG. 2. Closer view of some of the grain-grading apparatus.

14. U. S. Dept. Agr. Bul. 725. A preliminary study of the bleaching of oats with sulphur dioxid.
15. U. S. Dept. Agr., Bur. Plant. Indus. Cir. 74. The sulphur bleaching of commercial oats and barley.

IV. Laboratory practice.

A large number of samples of the different grains are obtained from various sources, such as the local experiment station, feed stores, and farmers of the State, and assigned to the students. The first laboratory period is used in demonstrating the use of the grain probe in obtaining samples and the apparatus used in grading, and in discussing various phases of the different operations. In the following laboratory periods the students are furnished with direction sheets to be followed in grading the assigned samples, and with the use of the small handbook, "Official Grain Standards" (8), and type ~~samples~~, the students are able to go ahead with a reasonable amount of help from the instructor.

The following are copies of the direction sheets used.

Directions for Grading Wheat.

1. Give your sample a laboratory number.
2. Make moisture test, using sample contained in air-tight can (see Manual, p 33–36). For all other determinations that portion of the sample contained in the cloth bag is used.
3. Determine odor, onions, and garlic, and live weevils or other insects injurious to stored grain.

REPORT ON WHEAT GRADING TESTS.

Sample number					
Percent of moisture					
Odor					
Percent of dockage					
Weight per bushel					
Damaged kernels:					
Total					
Heat damaged					
Foreign material:					
Total					
Other than cereals					
Class or subclass					
Wheats of other classes					
Grade					
Remarks					

4. Divide sample down to about 1,000 grams (see Manual, p. 31, 32).
5. Determine dockage, using the 1,000 gram sample (see Manual, p. 14 and 37–42).
6. Determine test weight per bushel, using the dockage-free wheat obtained in 5 (see Manual, p. 13 and 43).

7. Divide the sample down to three portions, A, B, and C, containing 25 to 65 grams each.
8. Using portion A, determine total damaged kernels, heat-damaged kernels, total foreign material, and foreign material other than cereal grains.
9. Using portion B, determine the class and subclass into which the sample should be placed by analyzing for color and texture.
10. Using portion C determine wheats of other classes.

DIRECTIONS FOR GRADING CORN.

1. Give your sample a laboratory number.
2. Make moisture test, using sample contained in air-tight can (see Manual, p. 33–36). For all other determinations use that portion of the sample contained in the cloth bag.
3. Determine odor, live weevil or other insects injurious to stored grain, and quality.
4. Divide sample down to about 1,000 grams.
5. Determine weight per bushel, using the 1,000-gram portion.
6. Divide down to 240 to 260 grams.
7. Determine foreign material and cracked corn (see Manual, p. 21).
8. Using the cleaned sample, determine total damaged and heat-damaged kernels.
9. Divide down to about 100 grams.
10. Determine color, using the 100-gram portion.

REPORT ON CORN GRADING TESTS.

Sample number				
Percent of moisture				
Odor				
Weight per bushel				
Foreign material and cracked corn				
Damaged kernels:				
Total				
Heat damaged				
Color or class				
Grade				
Remarks				

DIRECTIONS FOR GRADING OATS.

1. Give your sample a laboratory number.
2. Make moisture test, using sample contained in air-tight can. For all other determinations use that portion of the sample contained in the cloth bag.
3. Determine condition and general appearance.
4. Divide sample down to a portion of 500 to 600 grams.
5. Determine weight per bushel, using the 500-gram portion.
6. Divide down to three portions, A, B, and C, each containing 25 to 65 grams.
7. Using portion A, determine sound cultivated oats, heat-damaged (oats or other grains), and foreign materials.

When a sample contains an unusual amount of foreign material, make determinations for this factor on not less than 250 grams of the original sample, using the buckwheat sieve for removing the seeds and dirt,

recovering any small pin oats that may pass thru with the dirt by rescreening, then hand-pick the sample for any remaining foreign material.

8. Using portion B, determine percentage of wild oats.
9. Using portion C, determine percentage of other colors of cultivated and wild oats.

REPORT ON OAT GRADING TESTS.

Sample number.		
Percent of moisture		
Condition and general appearance		
Weight per bushel		
Sound cultivated oats		
Heat damaged (oats or other grains)		
Foreign material		
Wild oats		
Other colors cultivated and wild oats		
Color or class.		
Grade		
Remarks		

After completing the course as here outlined, the student has the fundamental principles of grain judging and will have a tendency in his later experiences in judging grains to lay stress upon facts brought out in such a course. The instructor has a chance to connect the various factors taken into consideration in the grade requirements with the practical value of the grains, and formulate in the students' minds the most practical score card to be used in judging grains at a grain show, on the farm, or in commerce.

In the course as it is now being conducted much interest and value has been added by a lecture by Mr. Harold Anderson, Grain Supervisor of this district, on "The Duties of the Grain Supervisor and his Relations to the Farmer," and a trip to Baltimore to inspect the supervisor's laboratory, the Chamber of Commerce trading floor and inspection laboratory, and a large grain elevator. Another factor which gives variety and interest to the course and seemed to be well worth while was the showing of the following motion picture films loaned by the United States Department of Agriculture:

1. The Story of Wheat in the Pacific Northwest, 2 reels.
2. Wheat: Transportation and Storage, 3 reels.
3. Wheat Grading Under Federal Supervision, 1 reel.

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SMOOTH-AWNED BARLEYS.[1]

HARRY V. HARLAN.

Barleys with smooth awns or partially smooth awns are so little known that, altho the term "smooth-awned" is descriptive, it rarely conveys the true meaning. This is because hooded and awnless varieties are frequently knows by such names as "smooth" and "bald." The hooded varieties are widely distributed, the Nepal being found in field culture in every barley-growing State, but awnless varieties are little known. In the hooded varieties, the awn is replaced by a three-pronged hood that extends slightly beyond the kernel, the prongs being turned backward. This hood is not harsh in structure as is the awn. The so-called awnless varieties have no awns on the lateral florets, but usually have short awns on the central florets.

The edges of the awns of the common rough-awned barleys are armed with closely-set projecting teeth which point toward the tip (fig. 15, *b*). The largest teeth are at the base of the awn, the teeth gradually decreasing in size until near the tip they are so small that the awn feels only slightly rough. In the smooth-awned sorts the teeth are almost entirely wanting (fig. 15, *a*). For all practical purposes, they are eliminated, altho all smooth-awned barleys are not equally smooth. The large teeth near the base are the first to disappear. Some varieties are smooth for two-thirds of the distance from the base to the tip, while others are smooth for four-fifths or more of the length. As the teeth on the upper third of the awn are not objectionable, all barleys of this class are essentially smooth-awned. These awns are so smooth that they may be pulled across the face in either direction without roughness being apparent except at the tip.

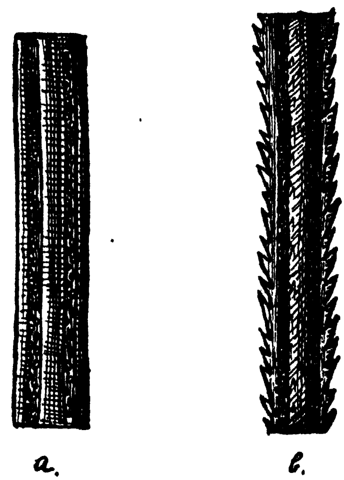

FIG. 15. Section of (*a*) smooth and (*b*) rough awns of barley (after Regel).

[1] Contribution from the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Received for publication April 5, 1920.

The economic advantage of smooth-awned barleys is considerable. The rough awns have limited the production of this grain in many ways. It is a disagreeable crop to handle during harvesting and thrashing and for this reason farmers often object to growing barley. Growers frequently have difficulty in exchanging labor at thrashing time, if their proportion of barley is large. The straw frequently causes sore mouths in animals, the pieces of awns piercing the membranes and being held there by the numerous curved teeth. When sheep are fed on barley, the awns work into the wool. In the West, barley is used much for hay and would be more widely grown for this purpose if it were not for the rough awns. Yield being equal, every farmer would prefer a smooth-awned variety, and if a high-yielding one can be found, it will doubtless result in an increased acreage of the crop.

Smooth-awned barleys are not new. They have been known in European botanical collections for many years. Koernicke described the *leiorrhynchum* form in 1882. In the same paper he described *medicum* and *persicum*; smooth-awned 2-rowed sorts that are found in mixtures of barley from Asia Minor.

Robert Regel in Russia has done very extensive work with smooth-awned varieties and published a monograph on them in 1909. He reported a considerable number of such barleys from Russia. Various Russian experiment stations have tested these varieties. So far as the writer knows, no pure culture of a smooth-awned barley has been grown commercially.

Little interest has been shown in smooth-awned barleys in North America. Smooth-awned stocks have been limited and the work done in Russia has not attracted the attention it deserved. The Office of Cereal Investigation of the United States Department of Agriculture has studied these forms for several years. A large part of the work has been in cooperation with the Minnesota Agricultural Experiment Station, where the writer became the representative of the United States Department of Agriculture in some cooperative barley investigations in 1909. At harvest time that year, a plant with partially smooth awns was found in a plat of Hanna barley, many strains of which show a tendency toward smoothness. The plant found had the teeth missing from the lower one-third of the awns. It was the intention to use the progeny of this plant in breeding operations to obtain a smooth-awned form, but other forms with fewer teeth were found in 1910. One plant was found in the Prinsess variety and one in a barley from southern Russia. In 1911 and 1912, crosses were made which included very smooth *H. leiorrhynchum* parents. One strain of

leiorrhynchum, while very smooth, had a weak straw and was replaced in most of the later crosses by a *leiorrhynchum* form received in 1912 from Russia. This importation was sent to the Office of Foreign Seed and Plant Introduction by F. H. Meyer from Taganrog in southern Russia. The Taganrog barley was not as smooth-awned as that used in 1911 and 1912, but it was much superior in every other way.

The F_1 generation of several crosses was grown in the greenhouse at Washington during the winter of 1912-1913. The seed from this was sown in May, 1913, at the Minnesota station. Counts of the progeny of the F_2 generation showed smoothness to be recessive. The breeding of smooth-awned sorts was thus found to be a very simple matter and several hundred plants were selected from crosses already made. The rough-awned parents included Manchuria, Mariout, and Coast. Many other crosses were made and a considerable number were in the F_1 generation at this time.

In 1913, seed of the Russian smooth-awned parent was sent to California, Idaho, and Michigan. Small lots of the Taganrog barley and lines obtained from various crosses were sent out in succeeding years until by 1917 smooth-awned strains were in the hands of experimenters from New York to California and some seed had been sent to Canada.

In the meantime, a smooth-awned barley had been received thru the Office of Foreign Seed and Plant Introduction, from Dr. Trabut of Algeria, in July, 1910. This, like the Taganrog barley, was a black 6-rowed form. Only a small quantity of seed was received and this was sent to California and Oregon under the name of Black Algerian (C. I. No. 708). The writer received none of the seed and did not learn of the existence of this variety until it had been grown for several years. It does not appear to be as smooth as the strains grown at St. Paul.

Other smooth-awned forms have been introduced thru the Office of Foreign Seed and Plant Introduction. These include two 2-rowed forms from Asia Minor, one white and the other black. Neither of these has been used in crosses. More recently a smooth-awned white 6-rowed form was received from Robert Regel. It is not known whether or not independent importations have been made. Partially smooth sorts have been isolated from our common barleys by the writer and doubtless by others. None of these that has been included in the experiments reported has been as smooth as the better strains of *H. leiorrhynchum.*

The breeding operations have been conducted at St. Paul, Minn.; Arlington Farm, Va.; Chico, Cal.; Aberdeen, Idaho; and Moro.

Oregon. A large number of crosses have been made, embracing a wide range of rough-awned parents. Several hundred strains have been isolated and studied. It has been found entirely practicable to secure segregates from all matings with the basal two-thirds of the awn smooth, no matter how rough the awn of the rough-awned parent may be. As we have no conception of the number of factors in a strain, it is hardly possible to say that the teeth of the awns of a variety can be removed by crossing. Types similar to the rough-awned parent except for the absence of teeth on the awns may be isolated readily, but it is extremely unlikely that the variety is not otherwise changed as well.

As barleys of this type have not yet been tested under farm conditions, and as most of the yields obtained are nursery yields, it is not thought worth while to present records of performance at this time. From the results to date, however, there seems to be no reason why high-yielding smooth-awned barleys can not be produced. The original importations of *H. leiorrhynchum* have yielded as well as the average importations of rough-awned barleys. Smooth-awned crosses have yielded well in the nurseries at various places, and these yields have been maintained over a series of years.

On the other hand, the absence of such varieties in commercial cultures in Europe and Asia indicates a weakness of some sort. Such forms have been known for many years. They must have been observed long ago by peasants in Asia Minor and southern Russia. Why has not such an attractive feature been utilized? At present we can not even guess, for so far the yields indicate that smooth-awned barleys may be made to give satisfactory harvests.

Smooth-awned barleys are still in the experimental stage. Several high-yielding strains adapted to different climatic conditions are ready for increase to larger plats and to field culture. Whether they can compete with rough-awned varieties remains to be determined.

AGRONOMIC AFFAIRS.

ANNUAL MEETING OF THE SOCIETY.

The thirteenth annual meeting of the American Society of Agronomy will be held at Springfield, Mass., October 18 and 19, 1920, in connection with the annual meeting of the Association of Land Grant Colleges.

NOTES AND NEWS.

W. E. Ayres, formerly assistant agronomist at the Arkansas station, is now agronomist at the Delta Substation, Stoneville, Miss.

M. A. Beeson, head of the department of agronomy at the Oklahoma college and station, resigned July 1 to engage in commercial work.

Manley Champlin, for several years associate agronomist of the South Dakota college and station and more recently extension agronomist, has resigned to become senior field husbandman in the University of Saskatchewan.

R. W. Clothier, for the past several years with the Federal Office of Farm Management, is now president of the New Mexico Agricultural College.

H. R. Cox is now extension specialist in crops and soils in New Jersey.

W. H. Darst, formerly associate professor of farm crops in the Pennsylvania college, has resigned to accept a position with the North Carolina A. & M. College.

Dr. Spright Dowell, state superintendent of education, has been elected president of the Alabama A. & M. College, effective July 1. The former president, Dr. C. C. Thach, has been made president emeritus.

Arthur T. Evans, formerly professor of botany and dean of Huron College, is now associate agronomist of the South Dakota college and station.

Ernest M. Fergus, formerly instructor in farm crops at Purdue University, is now connected with the department of agronomy in the University of Kentucky.

D. S. Fox, assistant professor of agronomy at the Pennsylvania college, has resigned, effective July 1.

E. F. Gaines, plant breeder at the Washington station, is on leave of absence beginning September 1, for postgraduate study at Bussey Institution.

H. H. Laude, formerly agronomist at the Texas station, is now in charge of cooperative experiments at the Kansas station. He is assisted by N. E. Dale, who has succeeded Bruce S. Wilson.

Guy R. McDole, assistant soil chemist at the Minnesota agricultural college and experiment station, has accepted the position of associate professor of agronomy and soil technologist at the University of Idaho.

Paul V. Maris, for four years state leader of county agents in Oregon, has been made director of extension in that state.

G. K. Middleton, associate professor of agronomy at the North Carolina college, has resigned to take up agricultural work at Kaipang, Hainan Province, China.

J. R. Nevius is now instructor in farm crops in the Oregon college.

J. S. Owens, formerly extension agronomist at the Pennsylvania college, is now on the field staff of the eastern bureau of the National Lime Association.

R. C. Parker, formerly county agent in Suffolk County, L. I., now represents the National Lime Association in New England and eastern New York, with headquarters at Springfield, Mass.

J. L. Robinson, formerly assistant agronomist at the Wyoming college and station, is now director of cooperative experiments in the farm crops department of Iowa State College.

Karl Sax, formerly engaged in plant breeding at Riverbank Laboratories, Geneva, Ill., has been appointed biologist at the Maine station in charge of plant breeding and has entered on his new duties.

Robert Stewart, for the past several years professor of soil fertility at the University of Illinois, is now dean of the college of agriculture of the University of Nevada.

Prof. Samuel Mills Tracy, formerly director of the Mississippi Agricultural Experiment Station, and for the past 23 years connected with forage-crop investigations of the Federal Bureau of Plant Industry, died at Laurel, Miss., September 4, 1920, aged 73 years. Professor Tracy was born in Hartford, Vt., April 30, 1847. He graduated from the Michigan Agricultural College in 1868 and received the degree of M.S. from the same institution in 1871. During the

civil war he was a private in Company A, 41st Regiment, Wisconsin Volunteers. He was professor of botany and horticulture at the State University of Missouri from 1877 to 1887, and director of the Mississippi Agricultural Experiment Station from 1887 to 1897. Since 1897 he has been engaged in a study of southern forage crops for the Bureau of Plant Industry, and during much of this time he has conducted an experiment station on his farm at Biloxi, Miss. During the past two years he has had charge of forage crop work at the McNeill, Miss., Substation. In addition to his forage crop investigations, Professor Tracy did much botanical work in connection with the flowering plants and fungi of the Southern States. Collections of his material are in many of the largest herbaria, and his own private collection is now at the Texas Agricultural College. Professor Tracy is the author of many bulletins of the U. S. Department of Agriculture and of the Mississippi Agricultural Experiment Station. He was a man of charming personality and his death is a distinct loss to his many friends and coworkers.

H. J. Webber has resigned as director of the California Agricultural Experiment Station to engage in commercial work, he now being connected with the Coker Seed Farms, Hartsville, S. C. He has been succeeded as director by Dr. C. M. Haring, formerly professor of veterinary science.

James Wilson, formerly professor of agriculture and director of the Iowa station, and Secretary of Agriculture in the cabinets of Presidents McKinley, Roosevelt, and Taft for the 16 years from 1897 to 1913, died at Traer, Iowa, August 26, at the age of 85 years.

The organization of the National Research Counsel for the year beginning July 1, 1920, is as follows: *Chairman,* H. A. Bumstead, professor of physics at Yale University; *1st vice-chairman,* C. D. Walcott, secretary of the Smithsonian Institution; *2nd vice-chairman,* Gano Dunn, president of the J. G. White Engineering Corporation; *permanent secretary,* Vernon Kellogg, formerly professor of zoology at Stanford University.

CONFERENCE ON ELEMENTARY SOIL TEACHING.

The following report of the Conference on Elementary Soil Teaching has been received from the Secretary, Prof. P. E. Karraker, of the University of Kentucky.

A very enjoyable and, it is believed, profitable meeting of soils instructors in the State agricultural colleges was held at the College of

Agriculture, University of Kentucky, June 23, 24, and 25, 1920. The purpose of the conference was a general discussion of the teaching of elementary soils in the State agricultural colleges. Attention was specially directed to the securing of greater uniformity in presenting this subject in the various colleges and to the determination of what should properly constitute the laboratory part of the work. The conference was called in response to a widespread feeling of need for such a meeting. Mention, however, should be made in particular of the very large part Dr. H. O. Buckman, of Cornell University, had in bringing it about.

A semi-permanent organization was effected by retaining the chairman, Prof. M. F. Miller, of the University of Missouri, and the secretary in their positions to facilitate such future action as may seem desirable. It was the feeling that meetings, such as this, of instructors in the various lines of work in the State agricultural colleges are well worth while and should be encouraged.

There was no feeling of finality in the results achieved by the conference and consideration and criticism by teachers not present is earnestly invited. It is believed, however, that the getting together of this group of instructors in discussion of their work and the specific recommendations resulting therefrom are a considerable advance toward the better teaching of soils.

The authorized report of the conference is as follows:

Representatives of the soil or agronomy departments of sixteen State agricultural colleges, assembled in conference at the University of Kentucky, June 23–25, 1920, agree upon the following recommendations:

"The first college course in soils should be a uniform general course known as the 'Principles of Soil Management.' This course should be required of all agricultural students and should carry approximately five semester hours credit.

"This course should deal largely with the scientific principles underlying the successful management of soils in general, with such practical applications as conditions demand.

"The minimum prerequisites of this uniform course should be one year of general inorganic chemistry, one term of general geology, and either high school or college physics.

"The subject matter of the course should be presented by well correlated lecture, recitation and laboratory work. At least three-fifths of the time should be utilized in lecture and recitation. Wherever practicable the work should be given in the Sophomore year. It is desirable that a standard text book be used.

"The laboratory exercises covering one semester hour's time should conform as nearly as possible to the following general outline; where two laboratory periods are used the quantitative method should be applied to this outline:

Rocks, minerals and weathering (one or more periods).
The soil particles and soil class (one period).
Volume weight determinations, either in the field or laboratory, with calculations (an optional one-period exercise).
Study of organic matter { Peat, muck or a highly organic soil. Maximum water as affected by organic matter. Estimation of organic matter, etc.
Study of soil structure either in field or laboratory, including a specific study of colloids. (The study of organic matter and structure shall cover one or more periods.)
Soil moisture. (Two or more exercises as conditions make necessary.)
    Optimum moisture and moisture determinations.
    Moisture determinations on field soil under different treatments.
    Maximum water capacity.
    Estimation of sòil moisture.
    Calculations, etc.
Soil heat (an optional one-period exercise.)
    Temperature of field soil.
    Heat conductivity, etc.
Absorption of nutrients by the soil. (An optional one-period exercise)
Soil reaction studies—acidity and alkalinity (one or more exercises).
Fertilizer materials and lime (two or more exercises).
Interpretation of soil survey reports and maps (one period).
At least one assigned problem in soil management to be presented and discussed at any time that may be convenient.

Note: Two or more field trips to be given after any of the following exercises: (1) soil class; (2) organic matter and structure; (3) soil moisture; (4) fertilizer materials and lime.

"The advantages of such a course are as follows:

"1. The student is able to obtain in one course a survey of the entire subject.

"2. The course will make possible the preparation of standard texts and illustrative materials and standard laboratory equipment.

"3. Such a uniform course will facilitate the transfer of credits from one institution to another."

The representation at the conference was as follows:

FIRMAN E. BEAR, Ohio State University;
H. O. BUCKMAN, Cornell University;
GEO. A. CRABB, Georgia State College of Agriculture;
L. F. GIESEKER, Montana State College;
T. B. HUTCHESON, Virginia Polytechnic Institute;
P. E. KARRAKER, University of Kentucky;

A. F. Kidder, Louisiana State University;
H. A. D. Leggett, University of Vermont;
R. B. Lowry, University of Tennessee;
A. G. McCall, University of Maryland;
C. Ernest Millar, Michigan Agricultural College;
M. F. Miller, University of Missouri;
Geo. Roberts, University of Kentucky;
R. S. Smith, University of Illinois;
Robert Stewart, University of Nevada;
D. C. Wimer, Pennsylvania State College;
Casper A. Wood, Agricultural and Mechanical College of Texas.

CONFERENCE OF WESTERN AGRONOMISTS.

The following report of the Conference of Western Agronomists has been received from Roland McKee of the United States Department of Agriculture.

The fourth annual conference of agronomists of the Rocky Mountain and Pacific Coast States was held at the University of California, Berkeley, June 8 and 9, and at the California Agricultural Experiment Station, Davis, Cal., June 10. The meeting was well attended, six States and the U. S. Department of Agriculture being represented. Prof. J. W. Gilmore of the University of California was chairman.

The program consisted of discussions of the following subjects:

Problems of Power in Tillage and Harvest;
Soil Problems Relating to Crop Production;
Farm Crop Diseases and Treatments;
Farm Crops and Seed Production and Utilization;
Problems Relating to Teaching and Leadership.

On the evening of June 8 three reels of motion pictures showing modern operations in wheat production were presented by J. A. Clark of the U. S. Department of Agriculture.

The problems of power in tillage and harvest were presented by Prof. W. J. Gilmore of the Oregon Agricultural College. The discussion indicated that much progress has been made in determining the place of tractor power on the farm, but it also seemed evident that varying local conditions make the application and use of tractors a problem for local consideration.

Dr. F. S. Harris, director of the Utah Agricultural Experiment Station, presented in outline form the alkali soil problems as related to crop production. The great importance of this subject to the agriculture of the West was emphasized and the complexity of the prob-

lems indicated. In spite of the handicaps, Doctor Harris is very optimistic of the possibilities of much good work being done. Emphasis was laid on the necessity of more knowledge on the subject so that the future possibilities and permanency of crop production on lands that may be developed under irrigation may be more accurately foretold.

The subject of farm crop diseases and treatments was presented by Prof. W. W. Mackie of the University of California. In connection with the treatment of seed grain for loose smut by the use of formaldehyde, recent work done at the University of California in cooperation with the U. S. Department of Agriculture has indicated that much damage may be done by allowing the seed to dry after treating or by sowing in dry soil. This is due to the formation of paraformaldehyde, which kills the germinating seed.

D. E. Stephens, superintendent of the Sherman County Branch Station, Moro, Oreg., and Prof. F. J. Sievers of Washington State College led in a discussion of some problems in soil tillage and rotation in cereals. Mr. Stephens had found in his work that anything that lengthens the season of maturing of wheat increases "yellow berry." The most common factors in this connection are nitrates, organic matter, and moisture. He has secured no difference in yields of grain following 5 and 8 inch depths of plowing. Similar results have been obtained at Pullman, Wash. Fall disking has been of no advantage. Early spring plowing has given better results than later spring plowing. The amount of moisture in the fall has been practically the same on fallow plats receiving good cultivation, poor cultivation, and no cultivation.

Many good points were brought out in these and other discussions in which the work being done at various institutions was presented.

The last day of the conference was spent at the University Farm, Davis, Cal., where opportunity was afforded for seeing the field experiments conducted at that point.

The conference in 1921 will be held in Arizona, the exact date to be determined by the directing committee, consisting of Prof. G. E. Thompson of the University of Arizona, Prof. J. W. Gilmore of the University of California, and Roland McKee of the U. S. Department of Agriculture.

MEMBERSHIP CHANGES.

The membership reported in the May JOURNAL was 538. Since then, 13 new members have been added, 3 have been reinstated, 2 have resigned, and 2 have died, making a net gain of 12 and a total present membership of 550. The names and addresses of the new and reinstated members, the names of those resigned and deceased, and such changes of address as have been noted, are as follows:

NEW MEMBERS.

BRANSTETTER, B. B., University of Missouri, Columbia, Mo.
FRIANT, R. J., Delaware College, Newark, Del.
GREEN, W. J., Experiment Station, Agana, Guam.
HADLEY, F. E., 101 California St., San Francisco, Cal.
JENSEN, IRVING, Agr. Expt. Sta., Logan, Utah.
KIRKPATRICK, ROY T., University of Missouri, Columbia, Mo.
MEYERS, M. T., 58 W. Frambes Ave., Columbus, Ohio.
PARKER, R. C., Box 505, Riverhead, N. Y.
POWERS, WM. H., Agricultural College, Brookings, S. Dak.
SEATON, JEROME P., Glencarlyn, Va.
ROHDE, W. C., Agriculturist, The Barrett Co., Baltimore, Md.
TOMPKINS, J. F., Burdette, Ark.
ZAHNLEY, J. W., Kansas State Agr. College, Manhattan, Kans.

MEMBERS REINSTATED.

FREEMAN, GEORGE F., Societe Sultanienne d'Agriculture, Cairo, Egypt.
SCOTT, HERSCHEL, Betteravia, Cal.
SNYDER, R. M., East Lansing, Mich.

MEMBERS DECEASED.

S. M. TRACY, H. FOLEY TUTTLE.

MEMBERS RESIGNED.

F. S. HAGY, C. K. MCCLELLAND.

CHANGES OF ADDRESS.

BIGGAR, H. H., The Dakota Farmer, Aberdeen, S. Dak.
BLAIR, R. E., Box 641, Porterville, Cal.
BRACKEN, JOHN, Agricultural College, Winnipeg, Manitoba.
BREITHAUPT, L. R., Ontario, Oregon.
BUIE, T. S., Agr. Expt. Sta., Clemson College, S. C.
CHAMPLIN, MANLEY, University of Saskatchewan, Saskatoon, Sask.
CROMER, C. O., Daleville, Ind.
DARST, W. H., A. & M. College, West Raleigh, N. C.
DULEY, F. L., 27 Allen Place, Columbia, Mo.
DUNLAVY, HENRY E., Italy, Texas.

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THE AGRONOMIST'S PART IN THE WORLD'S FOOD SUPPLY.[1]

F. S. Harris.

The welfare of mankind is intimately bound up with the world's food supply. Not that man can "live by bread alone," but he is unable to devote himself to the higher phases of an advancing civilization if he is conscious of the gnawings of hunger. Since the shortage in various food products during the war, people generally have taken a much keener interest in the whole question of food supply. The old statement that "we never miss the water till the well runs dry" is here exemplified. So long as the grocer had plenty of flour and sugar, most people considered the supply in much the same way as they considered the supply of air. The only worry was to find money with which to purchase needed articles.

When it became necessary to go to a dozen stores before being able to buy any sugar, and then only a pound or two; when the meat allowance was restricted; and when white flour had to be supplemented by all kinds of substitutes, then people began to realize that the supply of food might not be inexhaustible.

The shortage of food during the war has been a good lesson for the people of the United States. It has taught them what some of the people of Asia have been so often forced by famine to realize, namely, that food can be had only when a supply is available and that this supply may at times be far short of actual needs. Conditions during the war were of course unusual; we hope they will never recur. I do not at this time desire to consider the food shortage due to the war but rather the whole food situation as it is likely to affect man-

[1] Presidential address presented at the thirteenth annual meeting of the American Society of Agronomy, Springfield, Mass., October 18, 1920.

kind in the future as the population of the earth increases. There will be of course temporary local short-time food shortages due to unfavorable seasons, wars, or other unusual conditions. These situations will have to be met as best they can at the time. The thing to which I should like to direct attention at present is not this temporary or local condition of famine but rather the means by which people may be fed when the world becomes much more populous than it now is. Having an earth, the best land of which is already producing crops without any great surplus, how is it going to be possible for nations to grow, cities to be built, and civilization to advance? Is there a limit to the number of people for whom the earth can supply food, or can the increase go on indefinitely?

As a small boy I remember going through what seemed to me to be an immense forest with a man who said it contained enough timber to last the whole United States for a thousand years. Later, when I became old enough to make the calculation, I found that this particular body of timber would not furnish America's needs for a single year.

In the early days of the settlement of the West, many who saw the large rivers made the statement that the water of these streams could never be exhausted by irrigation. The supply was said to be limitless. Experience has shown that the water of many of these streams was exhausted before more than a fraction of the land adjacent to them could be served. Thus, all things have their limits. There is a limit to the number of people a given area of land can sustain and, as the area of land is practically constant, there must be a limit to the number of people that can be fed. The number of course depends entirely on how fully the resources of the earth are utilized. It is possible greatly to increase production. I wish later to call attention to the methods by which the agronomist may assist in accomplishing this end.

I am not an alarmist. I do not wish to appear as one who is trying to stir people up unnecessarily. I should not like even to take the responsibility assumed by Sir William Crookes, who, in his presidential address before the British Association for the Advancement of Science in 1898, set a date when the shortage of food would begin to be felt. I do not believe that sufficient data are available for anyone to be so definite. A few facts, however, may be used to help in clarifying our minds on the subject.

It is well known that the population of all important countries of the world is gradually increasing. During the 110 years from 1800

to 1910 the population of the world increased from 640,000,000 to 1,600,000,000, or an increase of 152 percent. Only a few generations ago there were vast continents of unsettled fertile land waiting to absorb the overflew from the populous parts of the world. There are still many large tracts of land that are not settled, but it is obvious to all who have made a study of the subject that the better lands are rapidly being put under cultivation, and only the more remote and more unfavorable areas remain. This does not say that there is not still available much excellent land; but let us consider the United States as an example.

In 1790 the population of the entire country was 3,929,214; by 1840 it had reached 17,059,453; while the 1920 census shows it to be more than 105,000,000. A century ago only the east coast was settled; the great heart of the agricultural land had not been touched. The rapidity of settlement of the Central States is indicated by the fact that between 1800 and 1820 the population of Ohio, Indiana, Illinois, Michigan, Wisconsin, and Iowa increased from 50,240 to 792,719, and by 1840 it had reached 2,967,840. Today the entire country has been thoroly explored and the better land has been producing for nearly a generation.

In order to see just how our production and consumption have balanced during the last three score and ten years—the allotted time of man—let us examine the figures for wheat, probably our best index crop.

TABLE 1.—*Average wheat production in and export from the United States by 10-year periods from 1849 to 1919.*

Year or decades.	Average annual production.	Average annual exports.	Percent of total crop exported.
	Bushels.	*Bushels.*	
1849	100,486,000	7,535,901	7.5
1859–1868[a]	190,395,750	21,475,072	11.3
1869–1878	285,951,600	73,634,732	25.7
1879–1888	446,587,600	133,703,079	29.9
1889–1898	495,184,800	165,377,944	33.3
1899–1908	651,643,800	152,533,604	23.4
1909–1918	754,471,400	172,400,807	22.8

[a] Average of only four years, 1859, 1866, 1867, 1868.

In 1849 we produced approximately 100,000,000 bushels of wheat in the country, only 7.5 percent of which was exported. With the rapid settlement of the West, production rose till during the decade from 1879 to 1888 it reached 446,587,600 bushels, 33.3 percent of which was exported. Thus new productive land was brought under

cultivation much faster proportionately than population increased. After this time, however, the population so gained on production that during the next decade only 23.4 percent of the wheat produced was exported, and during the ten years from 1909 to 1918 the exports averaged 22.8 percent of the production. This figure was much increased by enlarged exports due to the war. During the years immediately preceding the war the exportation of wheat had almost ceased. In 1800, 80.4 percent of our exports consisted of agricultural products, whereas in 1910 the percentage had dropped to 50.9 percent.

These figures are significant because they show that, even in a country like the United States where the area and resources seem to be almost limitless, it will not long be possible to continue to feed other than our own increasing population.

A condition that helps to bring this about is the rapidly increasing proportion of our city-dwelling population. In 1820 only 4.93 percent were urban. In 1880 this had reached 29.5 percent, leaving still 70.5 percent rural; ten years later 36.1 percent were urban and 63.9 percent rural; in 1900 40.5 percent were urban; and by 1910, 46.3 percent were urban and only 53.7 percent rural. The 1920 census shows that more than half of the people of the United States are living in cities.

With a condition of this kind the food situation is likely to become more acute than where most of the population live on the farm where they can more quickly influence the rate of food production. With the growth of many large cities and with the complex systems of modern transportation and exchange, the food question tends more and more to become a single whole-world problem rather than numerous small local problems affecting the smaller communities. With our modern systems unobstructed by war, we shall probably never again have such devastating local famines as were so common in past generations in India, China, and Russia during years when there was an abundance in other parts of the world.

The situation as it appears to me is this: We live in a world with an increasing population. This increase can not expand indefinitely to fertile unoccupied lands, for these lands are becoming scarce. The food supply must be increased as fast as the population increases, for food supply is the chief limiting factor in population growth.

There is no immediate cause for alarm, but it is the duty of scientists and statesmen to look to the future. We must not be content to be like Sam the negro, who took his stove to his boss and offered it for sale for a fraction of its value. On being asked if he would not

need it next winter he said he would but that winter was three months away while the circus was tomorrow!

Satisfying the needs of today is not sufficient. We must maintain a forward-looking attitude. It is impossible to make large increases in production quickly; years of preparation and work will be required to do anything of permanent value. An adequate solution of the world's food problem can be made only by deliberate planning. All factors involved must be considered and a world-wide program of work initiated, for the world is now a unit in production and in consumption.

The problem will involve a great variety of business and scientific interests. Credit, transportation, manufacturing, and mechanics must all be called on to do their part. What we are now most interested in, however, is the contribution of the agronomist. What is his part in the world's food problem?

An examination of the question indicates that his part is a large one. While it is not entirely clear just what is included under the word "agronomy," the general understanding is that it has to do with anything affecting crop production and, as the food supply is in the last analysis a question of crop production, it would appear that the agronomist has a great responsibility in seeing that the people of the world do not want for something to eat.

Let us see what means he has available to meet this responsibility. We have already shown that the increasing population will call for increased production. This increase can be met in just two ways: First, by extending the producing area, and second, by increasing the acre yield of the present cultivated area.

The method of enlarging the agricultural area will be discussed under the following four headings: (1) Increasing the irrigated area; (2) extending dry farming; (3) drainage of wet lands; and (4) reclamation of alkali lands.

Of course there are uncultivated lands in the world that will not require any of the methods of reclamation mentioned above to make them productive. They may be inaccessible, or for some economic reason it may not pay to cultivate them even tho they are fertile. In cases of this kind the agronomist has no particular responsibility. He is concerned primarily in solving the problems which call for his particular training in science. Since the better lands are already in use, most of the increased area will be made available largely by cultivating the less favorable lands.

The methods by which we shall increase the yield on lands that are

under cultivation will be discussed under the following three headings: (1) Increasing the fertility of the soil; (2) better tillage methods; and (3) the improvement of crops by breeding.

More than half of the surface of the earth receives insufficient precipitation for the most favorable growth of crops. The best method of making up this deficiency is through the application of water by irrigation. Unfortunately, the supply of water for this purpose is so limited that only a fraction of the land can be served. In many cases hundreds of thousands of acres of fertile land are found adjacent to a stream that does not contain enough water for a tenth of the land. In a case of this kind it is obvious that the volume of water and not the land area is the factor limiting production.

Here the agronomist's problem lies in the direction of making the limited water produce as much as possible for each acre foot. He must call in the engineer to help in storing the water of the flood season and making it available when it can be used by crops.

During the early days of irrigation no attempt at storage was made, but as the demand for water increased reservoirs were constructed, often at great cost. With the present structures, probably not more than half of the water in streams of the arid sections is fully used. The remainder runs to waste during high water or is lost through inadequate systems. One of the first steps that may be taken to increase food production is the construction of additional storage reservoirs and the improvement of canals to eliminate seepage losses.

Even the water that is delivered to the land falls far short of reaching its maximum duty. Many questions affecting the water economy of crops must still be investigated and there must be a wider application of principles of scientific irrigation before the available water will produce maximum crops. The periods when crops are most sensitive to water applications, the varying needs of different crops, the best methods of applying water to each type of soil, and numerous other similar questions must be investigated by the agronomist and taken fully into account before the arid regions can develop to their full fruition.

It is difficult to give exact figures, but it seems probable that when all possible economies are put into operation the irrigated area of the United States can be enlarged to about four times its present size. It is largely thru the agronomist, assisted by the irrigation engineer, that this enlargement can be brought about.

After all possible sources of irrigation water are fully utilized, there will be many millions of acres of arid land that can not be

served. The only possible chance for producing crops on this land is thru the methods of dry farming, which means that every process is directed toward moisture conservation.

Dry farming is essentially a branch of agronomy. It is based on a system of tillage that will store in the soil the moisture of one or two years till it is needed by crops. Its success depends on the selection of crops that can endure the rigors of drouth and the breeding of special drouth-resistant varieties.

Probably a larger area can be added to the present productive land by the conquest of drouth than by any other means, but drouth is a relentless enemy of crop production and its successful conquest will call for all the ingenuity of students of soils and crops. Part of the preliminary work has already been done, so that one now sees grain fields where only sagebrush was found a few years ago; but there still remain many difficulties to be overcome before all these vast areas can be made to serve the needs of man.

In humid sections great tracts of land are covered with swamps and produce no important human food. When reclaimed these lands are often exceedingly fertile. The drainage of some of the larger swamps offers rather serious engineering difficulties, but these can in most cases be overcome. The drained swamp with its peaty residue calls for special methods of management and fertilizing; but, as agronomists are seeking problems to solve, they will not be discouraged by the difficulties encountered in changing a drained swamp into a fertile field.

Somewhat related to the drainage of the swamp comes the reclamation of alkali land, for it is largely through drainage that alkali is overcome. In all arid parts of the world the soil is likely to contain such an excess of soluble salts that crops can not be raised. This condition becomes more acute under irrigation. At present in the United States there are millions of acres of land that fail to produce good crops chiefly because they are impregnated with salts. In some of the western States alkali is considered to offer one of the most important and difficult problems affecting agriculture. It will be met by drainage, by special soil treatment, by breeding more resistant crops, and in other ways that agronomists may devise. The problem is now waiting; its solution will mean more food for the world.

Since 1840, when Liebig explained how crops feed, great progress has been made in increasing the productivity of the soil. Before the rôle of mineral matter in the growth of plants was understood, all sorts of theories were advanced concerning the food used by plants

and as a result many inconsistent practices of fertilizing the soil grew up. When the real basis of plant nutrition was determined, the beginning of a rational use of fertilizers was at hand. This has resulted in increasing very materially the crop yields of many soils.

Just how much the acre yield can be increased is uncertain. We are sure that by the proper use of fertilizers, by rotation, and by better tillage methods the present cultivated area may be made to produce very much more than it is now producing, but the acre yield can not be increased indefinitely.

Last year, in his presidential address before this Society, Doctor Lipman ably discussed the nitrogen problem in its relation to increased food production. Each element entering into commercial fertilizers might have been discussed by him with equal interest, so many are the problems surrounding the supplying of food to plants. Agronomists may be sure that they have not yet discovered every method of increasing soil fertility by the use of fertilizers. As the needs for food become more pressing, many additional discoveries will result from the researches of students of the soil.

Superior tillage methods, better rotations, and many other improvements in soil management may be expected to contribute to the increasing of the yield of the present cultivated area.

So much has been done during the last few generations to improve crops that we should hesitate before placing any limit on what may be accomplished in this respect in the future. The discovery of some of the fundamental principles of heredity has made progress much more rapid during the last few years than previously when everything was done by the hit-and-miss method.

If no additional land could be added to the cultivated area and if there were no way to increase the fertility of the soil, considerable relief in the food situation might in time come from the breeding of crops alone; but when this method can be taken in connection with the others, it becomes an especially valuable tool. For example, there are almost unlimited possibilities in developing crops suited to resisting drouth, soil alkali, or other unfavorable conditions in which ordinary crops can not thrive. But here too there is a limit to possible improvements.

From the foregoing, it is evident that the agronomist will be able to render valuable service in insuring an adequate food supply for the increasing population of the world. The question now arises as to what is his duty in the matter. Should he sit idly by as a disinterested spectator and allow things to take their natural course, or

should he assume initiative and take an active part in helping to forestall trouble? Will he be one who will give the ounce of prevention, or will he wait till the pound of cure is required? Probably both courses will be taken.

He who is progressive, he who takes his work seriously and is anxious to use his training for the welfare of his fellows, will doubtless take the more positive attitude and devote himself energetically to the solution of the many problems that crowd upon him. Only by profound research can these problems be solved; but he who devotes himself honestly to seeking these solutions will find joy unspeakable and will render a lasting service to mankind.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the September–October JOURNAL was 550. Since that report was made, 7 new members have been added and 1 has resigned, making a net membership at this time of 556. This does not take into account the fact that the dues of nearly 100 members have not been paid for 1920, which will reduce the membership by that number when these lapses are reported in the January issue. It is hoped that in the meantime a considerable part of these dues can be collected and that a large number of new members for 1921 will be added. The names of new members and of the member who has resigned, together with such changes of address as have been reported, are as follows.

NEW MEMBERS.

BLAIR, A. W., Agr. Expt. Station, New Brunswick, N. J.
CROCKER, LEO D., High School, Jameson, Mo.
DELP, H. T., High School, Boonville, Mo.
EVANS, A. T., Agronomy Dept., College of Agr., Brookings, S. Dak.
FUNK, ERNEST, High School, Seymour, Mo.
McQUEEN, JACOB, Baltic, Ohio.
MIRASOL, JOSE J., College of Agr., Los Banos, Laguna, P. I.

MEMBER RESIGNED.

ENGLE, C. C.

CHANGES OF ADDRESS.

ALLYN, ORR M., 618 So. First St., De Kalb, Ill.
BUIE, T. S., Experiment Station, Florence, S. C.

CLARK, CHAS. F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
COOPER, H. P., Dept. Farm Crops, Cornell Univ., Ithaca, N. Y.
CORMANY, CHAS. E., Mich. Agr. College, East Lansing, Mich.
DEYOUNG, WM., Kingston, Mo.
DYNES, O. W., University of Tennessee, Knoxville, Tenn.
FISHER, F. A., Farm Bureau, Mt. Carmel, Ill.
FULLER, F. E., Henry, Ill.
GARBER, R. J., Dept. Agron., Univ. of W. Va., Morgantown, W. Va.
HASKELL, S. B., Agr. Exp. Sta., Amherst, Mass.
HINDE, R. R., P. O. Box 1230, Greeley, Colo.
LAUDE, H. H., Kansas State Agr. College, Manhattan, Kans.
LOOMIS, HOWARD, 205 Michigan Ave., South Haven, Mich.
MCMILLAN, S. A., Anchor, Texas.
MERKLE, F. G., Dept. Agron., State College, Pa.
MITCHELL, JACOB N., 817 Pierce Bldg., St. Louis, Mo.
MOORE, HARVEY L., Western Union Tel. Co., Cape May, N. J.
OWENS, J. S., Agricultural College, Storrs, Conn.
PETRY, E. J., General Delivery, Brookings, S. Dak.
ROTHGEB, B. E., Bureau of Markets, U. S. Dept. Agr., Washington, D. C.
RUNK, C. R., Delaware College, Newark, Del.
SLIPHER, JOHN A., Natl. Lime Assn., Mather Bldg., Washington, D. C.
SMITH, N. S., Claresholm, Alberta, Canada.
TRACE, CARL F., Royster Guano Co., 321 W. Manhattan Blvd, Toledo, Ohio.
WEEKS, CHAS. R., Secy. State Farm Bureau, Manhattan, Kans.
WELCH, JOHN S., Jerome, Idaho.
WERMELSKIRCHEN, LOUIS, 1414 University Ave., Des Moines, Iowa.
WINTERS, N. E., 213 College Ave., Ithaca, N. Y.
WOODARD, JOHN, 619 Agricultural Bldg., Urbana, Ill.
WUNSCH, W. A., Argonia, Kans.
YOST, T. F., Co. Agent Hodgeman Co., Jetmore, Kans.

NOTES AND NEWS.

M. A. Beeson has recalled his resignation, announced some time ago, and will remain as head of the department of agronomy of the Oklahoma college.

A. M. Christensen has resigned as instructor in agronomy at the Northwest School of Agriculture, Crookston, Minn.

H. P. Cooper, formerly of the Massachusetts College of Agriculture, is now connected with the farm crops department of Cornell University.

Chas. E. Cormany is now instructor in farm crops at the Michigan college.

R. J. Garber, formerly of the Minnesota college, is now assistant agronomist at the West Virginia college and station.

REPORT OF THE SECRETARY-TREASURER.

This report covers the period from November 1, 1919, to October 15, 1920. During this period 72 new members have been added to our active membership, 7 reinstated, 11 resigned, 3 died, and 102 allowed their membership to lapse through nonpayment of dues. As we started the year with an active membership of 473, the record shows a new loss of 37 and a total active membership of 436. Thirty-five subscribers to the JOURNAL have failed to renew their subscriptions, leaving a subscription list of 82.

How to prevent this large loss each year is a problem I have been unable to solve. It is very discouraging work to build up the membership of a society by the addition of new members only to be confronted with a loss of one-fifth of the old members because of nonpayment of dues. This loss in membership is specially unfortunate at this time when the cost of printing the JOURNAL has been substantially raised.

The question must be faced by the Society whether to cut the size of the JOURNAL to bring it within our income or to provide additional funds. The Secretary has done a considerable amount of corresponding with advertising agencies in an effort to get them to take on the JOURNAL on a basis that would yield a profit to the Society. Two objections are raised. The size of the JOURNAL does not permit the use of a standard 5 × 8 inch plate and the mailing list is too small to appeal to advertisers. By enlarging the size of the JOURNAL to a standard 7 × 10 inch page it would be possible to offer it in a group with agricultural college publications and derive some revenue from advertising. If any such change were made it should start with the January issue.

The only other alternative in the matter of increasing funds appears to be the raising of dues to members and the rate of subscription to libraries. My personal opinion is that an increase of dues will further deplete our membership and that the best thing to do is to reduce the amount of printing, which amounts to over 85 per cent of our expenses, to keep within our income. At the present time the burden of supporting the Society is borne by approximately one-third of the agronomists of the country. Whenever the other two-thirds take sufficient interest in the Society to join, it will be possible to maintain the JOURNAL at its present standard.

My work in the Department of Agriculture is of such a nature that I am absent from my office sometimes for weeks and months at a time, when it is not feasible to keep up with the duties of Secretary-Treasurer. In justice to the Society I must ask to be relieved from further responsibility in that position. I wish at this time to thank the members of the Society for their many courtesies during the three years I have served.

FINANCIAL STATEMENT FROM NOVEMBER 1, 1919, TO OCTOBER 15, 1920.

Receipts.

Balance on hand from previous year			$ 528.02
Dues from members:			
11 members for 1919	at $2.50	$ 27.50	
1 member for 1919	at 1.00[a]	1.00	
1 member for 1919	at .50[a]	.50	
366 members for 1920	at 2.50	915.00	
1 member for 1920	at 1.50[b]	1.50	
71 new members for 1920	at 2.50	177.50	
1 new member for 1920	at 2.00[a]	2.00	
1 member for 1921	at 2.50	2.50	
2 members for 1921	at 1.00[d]	2.00	
2 members for 1921	at .50[d]	1.00	
			1,130.50
JOURNAL and *Proceedings*:			
1 subscription for 1919	at 2.25[c]	2.25	
1 subscription for 1919	at 2.50	2.50	
31 subscriptions for 1920	at 2.50[e]	69.75	
40 subscriptions for 1920	at 2.50	100.00	
6 subscriptions for 1921	at 2.50	15.00	
5 subscriptions for 1921	at 2.25[e]	11.25	
Sale of volumes previous to 1920		196.00	
Sale of reprints		152.15	
			548.90
Total receipts			$2,207.42

[a] In arrears from 1919.
[b] Paid $1.00 in 1919.
[c] Fifty cents still due Society.
[d] Advance payment.
[e] Secured through agents.

Disbursements.

1919.		
Nov. 4.	Postage	$ 9.00
Nov. 8.	Printing programs Chicago meeting	6.18
Nov. 17.	Postage	2.66
Nov. 18.	Use of lantern, Chicago meeting	20.00
Dec. 22.	Postage	15.00
Dec. 27.	Postage	.97
1920.		
Jan. 20.	Maurice Joyce Engraving Co	17.95
Jan. 20.	Refund on JOURNALS and *Proceedings* ret'd	8.50
Jan. 31.	500 bill heads	4.75
Feb. 7.	400 circular letters	4.25
Feb. 28.	Postage	13.00
Mar. 10.	Maurice Joyce Engraving Co	64.97
Mar. 31.	Postage	.80

April 9.	Postage	1.44
April 28.	Postage	.26
May 3.	Postage	1.36
May 3.	New Era Printing Co.	1,347.48
May 24.	Postage	7.40
June 6.	Postage.	6.00
June 17.	Maurice Joyce Engraving Co.	10.70
June 24.	Notarial fees	1.00
June 24.	1,000 bill heads	7.00
June 24.	Postage	.94
July 7.	Refund of overpayment for reprints	5.88
July 7.	New Era Printing Co.	118.91
Sept. 18.	Postage	13.39
Sept. 18.	Postage	.78
Sept. 18.	Notarial fees	.75
Sept. 18.	New Era Printing Co.	356.37
Sept. 20.	Maurice Joyce Engraving Co.	14.50
Oct. 13.	Mary R. Burr, refund for postage	2.00
Oct. 13.	Mary R. Burr, clerical services	25.00
	Total disbursements	2,089.79
	Balance on hand	117.63
		$2,207.42

MINUTES OF THE THIRTEENTH ANNUAL MEETING.

SPRINGFIELD, MASS., October 18 and 19, 1920.

First Session, Monday Afternoon, October 18.

The session was called to order at 2 p. m. by President Frank S. Harris. In the absence of the Secretary, Lyman Carrier, Dr. C. R. Ball was nominated and elected Secretary *pro tem.* The session was devoted to a symposium on teaching agronomy, with speakers and topics as given below. It is noteworthy that every speaker was present and every paper presented in its printed sequence.

Prerequisites for Agronomic Subjects, by L. E. Call, Kansas State Agr. College, Manhattan, Kans.

The First College Course in Field Crops, by W. L. Slate, Jr., Connecticut Agr. College, Storrs, Conn.

The Standardization of Courses in Field Crops, by J. B. Wentz, Maryland State University, College Park, Md.

The Teaching of Soils in Agricultural Colleges, by W. H. Stevenson and P. E. Brown, Iowa State College, Ames, Iowa.

The Teaching of Soils, by A. B. Beaumont, Massachusetts Agr. College, Amherst, Mass.

The Teaching of Soils and Its Relation to Crop Subjects, by M. F. Miller, University of Missouri, Columbia, Mo.

Prof. A. B. Beaumont of the Massachusetts Agricultural College extended to the Society an invitation from that institution to visit the college at 4 p.m.

on Tuesday, with opportunity to see the intensive tobacco and onion culture in that portion of Connecticut Valley, a visit to the college and the experiment plats, dinner in the college hall and the business meeting following. On motion, the invitation was accepted. About 60 were present at the afternoon session. The following committees were appointed by the President:

Nominating Committee, L. E. Call, C. R. Ball, W. H. Stevenson.

Resolutions Committee, E. O. Fippin, Robert Stewart, Geo. J. Bouyoucos.

Auditing Committee, George Roberts, M. F. Miller.

Second Session, Monday Evening, October 18.

The second session was a joint meeting of the American Society of Agronomy and the Society for the Promotion of Agricultural Science. It was called to order at 8 p.m. by Dr. J. G. Lipman. The annual address of each of the retiring presidents was given as follows:

The Agronomist's Part in the World's Food Supply, by Dr. Frank S. Harris, President of the American Society of Agronomy.

The Future of Agricultural Science, by Dr. R. W. Thatcher, President of the Society for the Promotion of Agricultural Science.

A third paper illustrated by lantern slides followed the presidential addresses. It was entitled "Methods and Results of Mosquito Extermination in New Jersey," by Dr. Thomas J. Headlee, Entomologist of the State University of New Jersey. About 100 were present.

Third Session, Tuesday Morning, October 19.

The session was called to order by President Harris at 9 a.m. The President asked Prof. C. G. Williams of the Ohio Agricultural Experiment Station, First Vice-President of the Society, to occupy the chair. The symposium subject for the entire day was liming, and the following papers were presented, with an attendance of about 50:

The Need of Lime as Indicated by the Relative Toxicity of Acid Soil Conditions to Different Crops, by B. L. Hartwell, Rhode Island Agr. Expt. Sta., Kingston, R. I.

The Influence of Calcium Salts on the Growth of Seedlings, by R. H. True, Univ. of Pennsylvania, Philadelphia, Pa.

Liming in its Relation to Injurious Organic Compounds in the Soil, by S. D. Conner, Purdue Univ. Agr. Expt. Sta., La Fayette, Ind.

The Comparative Effects of Various Forms of Lime on the Nitrogen Content of the Soil, by C. A. Mooers and W. H. MacIntire, Tennessee Agr. Expt. Sta., Knoxville, Tenn.

The Influence of Liming on the Availability of Soil Potassium, Phosphorus and Sulfur, by J. K. Plummer, North Carolina Agr. Expt. Sta., Raleigh, N. C.

The Nature of Soil Acidity with Regard to its Quantitative Determination, by W. H. MacIntire, Tennessee Agr. Expt. Sta., Knoxville, Tenn.

Fourth Session, Tuesday Afternoon, October 19.

At 2 p.m. the session was opened by President Harris, with an attendance of more than 60 persons. Owing to the illness of Dr. T. L. Lyon he was not able to be present, and his paper, entitled "The Effect of Liming on the Com-

position of the Drainage Water of Soils," which had been prepared and submitted, was read by title only. The remainder of the papers in the liming symposium were then presented in order as follows:

The Comparative Values of Burnt Lime and Limestone of Different Degrees of Fineness, by Wm. Frear, Pennsylvania Agr. Expt. Sta., State College, Pa.

Comparison Between Magnesian and Non-magnesian Limestones, by A. W. Blair, New Jersey Agr. Expt. Sta., New Brunswick, N. J.

The Value of Liming in a Crop Rotation with and without Legumes, by J. G. Lipman, New Jersey Agr. Expt. Sta., New Brunswick, N. J.

Liming as Related to Farm Practice, by Frank D. Gardner, Pennsylvania Agr. Expt. Sta., State College, Pa.

Owing to the plan to visit the Massachusetts Agricultural College and surrounding territory, beginning at 4 o'clock, the final paper of the program by Dr. W. J. Spillman and the business meeting were postponed to an evening session at Amherst.

At 4 o'clock the members, to the number of 30 or 40, were taken by automobile thru the Connecticut Valley for a distance of 35 miles or more, on the west side, and then brought down the east side of the valley to the Massachusetts Agricultural College, which lies about 24 miles north of Springfield. Opportunity was given to see the intensive production of tobacco and onions, the latter at the northern end of the tobacco area. On arrival at the college, the fertilizer experiments were explained by Director Haskell and a brief inspection was made of Stockbridge Hall, tho agricultural building. The party then adjourned to the private dining room of Draper Hall, where dinner was had, followed by the annual business meeting.

Annual Business Meeting, Tuesday Evening, October 19.

The meeting was called to order by President Harris in the dining hall at Massachusetts Agricultural College. The minutes of the previous meeting were not present, but as they had been printed in the JOURNAL for December, 1919 (v. 11, p. 346–348), they were approved as printed. In the absence of the Secretary-Treasurer, Lyman Carrier, the report of that officer was read by Prof. M. F. Miller.

The report of the Auditing Committee was then read by Professor Miller, as follows:

REPORT OF AUDITING COMMITTEE.

We, the undersigned Auditing Committee, have examined the financial report and receipted vouchers for disbursements as submitted by the Secretary-Treasurer of the American Society of Agronomy and find it correct.

(Signed) GEORGE ROBERTS,
M. F. MILLER.

On motion the report of the Secretary-Treasurer as read was approved. In discussion of this report President Harris urged that a systematic effort be made to increase the membership to 1,000 in order that the journal of the society might be properly financed under present conditions of printing costs.

On motion, the report of the Auditing Committee was approved.

The report of the Nominating Committee was read by Chairman L. E. Call, and the following officers were placed in nomination:

President, Prof. Charles A. Mooers, Agronomist and Vice-Director of the Tennessee Agricultural Experiment Station.

First Vice-President, Dr. S. B. Haskell, Director of the Massachusetts Agricultural Experiment Station.

Second Vice-President, Dr. Charles B. Lipman, Soil Chemist and Bacteriologist of the California Agricultural Experiment Station.

Secretary-Treasurer, Dr. Percy E. Brown, Chief Soil Chemist and Bacteriologist of the Iowa Agricultural Experiment Station.

Member of the Advisory Committee on Agronomy to the National Research Council (for 5 years), Dr. Robert Stewart, Dean of Agriculture of the University of Nevada.

On motion, the report of the Nominating Committee was accepted and the Secretary instructed to cast the unanimous ballot of the Society for the nominees named, after which they were declared elected to the respective offices.

The report of the Resolutions Committee was read by Chairman E. O. Fippin. Resolutions were presented and, on motion, were adopted:

1. Thanking the New England agronomists and the Massachusetts Agricultural College for their courtesy and hospitality.

2. Thanking the Program Committee, Messrs. Ball and Mooers, for the symposium programme prepared for the society.

A third resolution asking that the Society adopt the principle of symposia in charge of qualified persons as the proper basis for future programs was discussed and action thereon deferred.

The reports of the following standing committees, as printed elsewhere in this issue, were then read and accepted:

Committee on Terminology, read by Chairman C. V. Piper.

Committee on Standardization of Field Experiments, A. T. Wiancko, Chairman, read by the Secretary pro tem.

Committee on Varietal Standardization, R. A. Oakley, Chairman, read by Prof. C. V. Piper.

Advisory Committee on Agronomy to the National Research Council, read by Chairman C. V. Piper.

No report was presented by the Committee on Soil Classification and Mapping and as those engaged in soil survey activities have formed a new national organization which will officially investigate and continue this work, it was moved to discontinue this committee. The motion was carried.

On motion of Prof. L. E. Call, the formation of a new committee on teaching agronomy was approved, the committee to be named by the newly-elected President.

The third resolution presented by the Committee on Resolutions, on which action was deferred earlier in the meeting, was now brought up. After considerable discussion in which symposium programs for a part of the sessions, under the leadership of specially qualified persons, were warmly advocated, it was moved to approve this resolution and the motion was carried.

The report of the Editor, C. W. Warburton, as printed elsewhere, was read and accepted. Mr. Warburton stated in connection to his report that he felt it necessary to resign the editorship, but as the editor is selected by the Executive Committee and not elected by the Society no action was taken. On motion, a vote of thanks and appreciation was tendered to the editor for his long and faithful service.

A discussion of the state of the membership and finances of the Society then followed. The renewal and increase of the local sections organized previous to the war was advocated by Mr. Warburton and on his motion the dues of the Society were increased from \$2.50 to \$3.00 annually.

The business meeting having been concluded, the program session was resumed and the paper by Dr. W. J. Spillman, entitled, "An Interpretation of the Results in Ohio Bulletin No. 336," was read.

The Society then adjourned.

Respectfully submitted,
C. R. BALL,
Secretary pro tem.

REPORT OF COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

The Committee on Standardization of Field Experiments is continuing studies and observations on methods of conducting field experiments with crops and soils and keeping in touch with the literature of the subject. It has not been possible to have a meeting of the committee this year but the members have been in touch thru correspondence. While it is felt that the Society must be careful about going on record as favoring certain systems and practices, it is hoped that agreement can soon be reached on at least a few fundamentals which the Society can adopt and stand for.

A few investigators are actively engaged in studying methods of field experimentation and contributing information that will be valuable in formulating standards for particular kinds of work. The committee earnestly recommends that all who can possibly do so should undertake some comparative study along this line because only by comparison can we hope to find what is best.

Respectfully submitted,
A. T. WIANCKO,
S. C. SALMON,
A. C. ARNY,
Committee.

REPORT OF COMMITTEE ON TERMINOLOGY.

Your committeee begs to report that in spite of no new published contributions, it has not been inactive, but has accumulated a great amount of material toward a completed glossary. It appears inevitable that agronomy must have a larger number of new technical terms so as to avoid ambiguity in meaning, a fault that is conspicuous in many technical papers. Perhaps we shall be forced to employ relatively as many special terms as does medicine. While there is valid objection to the introduction of new terms by the wholesale, your committee feels that this onus is one they must bear, as individuals are timid about proposing novelties in terminology.

We ask for your continued patience, but pledge our efforts to complete the glossary in the not distant future.

C. V. PIPER, *Chairman*,
C. R. BALL,
H. L. SHANTZ.

REPORT OF COMMITTEE OF VARIETAL STANDARDIZATION.

At the annual meeting of the American Society of Agronomy held in Chicago in 1919, a Committee on Varietal Standardization was appointed by the President of the Society for the purpose of considering nomenclatorial matters with regard to varieties of staple cultivated crops. The following were named by the President as members of the committee: Prof. E. F. Gaines, Washington Agricultural Experiment Station; Prof. George Stewart, Utah Agricultural Experiment Station; Prof. J. H. Parker, Kansas Agricultural Experiment Station; Dr. H. H. Love, Cornell University Agricultural Experiment Station; J. Allen Clark, Bureau of Plant Industry; Dr. L. H. Smith, Illinois Agricultural Experiment Station; Prof. H. K. Hayes, Minnesota Agricultural Experiment Station; H. G. Hastings, of Hastings Seed Co.; A. B. Conner, Texas Agricultural Experiment Station; and R. A. Oakley, Bureau of Plant Industry, *Chairman*.

After notice of appointment was received from the President of the Society, the chairman of the committee took up correspondence with the various members for the purpose of obtaining suggestions as to the most promising lines along which it was thought practical good might be accomplished. Some very constructive suggestions were offered, and tentative plans were made by the chairman for a meeting of the committee at the annual meeting of the Society in 1920. Subsequent correspondence with the members of the committee disclosed the fact that few, if any, would be present at the annual meeting at Springfield and, therefore, it is thought that it will be necessary to do most of the work for the coming year thru correspondence.

In going over the suggestions that have been offered by members of the present committee and those offered by similar committees in the past, the Chairman is of the opinion that the greatest good that the committee can hope to accomplish will be along the line of formulating rules of nomenclature and the organization of permanent machinery whereby these rules may be constantly called to the attention of those working on varietal classification and to act as a court of reference in the case of controversies. It was thought at one time that field work might be planned and executed in a very helpful way, but at present it does not appear that it would be feasible to attempt work of this nature. There are a number of pieces of classification work under way and it is believed that assistance can best be rendered by this committee in the nature of cooperation and coordination in connection with existing activities.

Various sets of nomenclature rules have been proposed by members of the American Society of Agronomy and other agronomic workers, and there seems to be a considerable difference of opinion with regard to the rules that should be followed. It is hoped that the Committee on Varietal Standardization will be able to reach some definite agreement as to rules of nomenclature and will also formulate workable plans for establishing and maintaining a Referee

Board to which all controversial questions of nomenclature may be referred. The chairman has submitted this proposal to the members of the committee, but they have had no time to reply. If they concur in these views, sub-committees will be appointed in order that definite and early action may be taken.

Respectfully submitted,

R. A. OAKLEY,
Chairman.

REPORT OF THE ADVISORY BOARD.

Your Advisory Board appointed to establish cooperative relations with the National Research Council begs to report that on March 20, 1920, it held a conference with the National Research Council in Washington, D. C. At this meeting were present Messrs. Call, Lipman, Mooers, Piper, and by invitation Marbut and Warburton. The whole day was devoted to a full discussion of the activities and needs of the American Society of Agronomy both as regards education and as regards research. Based on the discussions at this meeting, your Board presented a formal resolution to the Council under date of April 27, 1920. A digest of this resolution indicates its general content.

1. Detailed information regarding the American Society of Agronomy.

2. The status of the Journal of the American Society of Agronomy, which showed the need for financial assistance. A request for a contribution of $1,000 annually to aid in the publication of this journal was presented.

3. Coordination of agronomic research.—Agronomic research, particularly as regards field experimentation, requires large sums of money. The present appropriations are very inadequate. The investigations, both Federal and State, are, for reasons outlined, not well coordinated. The Advisory Board believes that efficient coordination can be secured best by the mutual efforts of the agronomic investigators themselves, by: (a) better planning of experiments; (b) mutual helpful criticisms of plans for securing data and of interpretation of results; (c) providing a desirable amount of duplication; (d) removing needless duplication of efforts; (e) keeping workers informed as to projects of investigation; (f) assisting to protect encroachment on research funds. In the judgment of the Advisory Board, the efficiency of agronomic research can be doubled with the present appropriations. Some assistance in such a program will doubtless be rendered by Federal and State agricultural institutions, but additional funds are vital to the success of the undertaking. It was requested that the National Research Council appropriate $10,000 annually to attain the ends desired. It is in every way desirable to promote this project as rapidly as possible, as it can be done independent of a survey of agricultural research (see proposal 4) and will do much to assist that survey if undertaken.

4. Survey of agricultural research.—Agricultural research in the United States has, like Topsy, "just grew." From the nature of its organization, all parts being more or less interallied, and with only nominal general supervision, there is need of a broad investigation to ascertain the strong and weak points of the whole as at present developed. The Advisory Board of the American Society of Agronomy requests that this be made a special feature of the investigations of scientific research institutions now being made by the National Research Council. It would be desirable to have this investigation

cover not agronomy alone but all agricultural research. If this proposal is adopted, the Advisory Board will be glad to furnish the Council information on many points that require consideration, not only in agronomy but in other agricultural subjects. A broad survey of the field of agricultural research will almost certainly result in findings of great importance to scientific and national welfare.

5. Suggestions as to sources of funds.—In this memorandum, a considerable list of financial and industrial institutions directly interested in the prosperity of agriculture was presented as likely sources of donations of funds for agronomic purposes.

6. Memorial urging the Council to adopt some method of publicity by which scientific men may exert a larger influence in matters that concern governmental policy and administration in scientific and particularly agricultural projects. The essential feature of this memorial is to bring about a better education of the public regarding the needs of agricultural research and the types of projects that need much greater support. At the present time the determination of these matters both in their inception and in their execution is mainly by nonscientific men. It is believed that a more aggressive attitude in regard to the broader problems of investigation will result appreciably in the betterment of State and governmental scientific work.

Respectfully submitted,

C. V. Piper, *Chairman,*
J. G. Lipman,
John W. Gilmore,
L. E. Call,
C. A. Mooers.

REPORT OF THE EDITOR.

The Journal of the American Society of Agronomy during 1920 has been hard hit by the high cost of living and of printing. The volume is the smallest which has been issued since the publication of a journal was begun in 1913. With the final number for the year, which will contain the President's address and the minutes of the annual meeting, it will contain not to exceed 248 pages as compared to 356 pages printed a year ago, and 400 pages or more in the preceding three volumes. The present volume contains 26 papers, illustrated with 8 plates and 15 text figures. These papers are by 25 authors, located in 13 States, the District of Columbia, and Guam. The principal source of contributions is the United States Department of Agriculture, 10 papers having originated there, while not more than two came from any other institution.

The reduction in size of volume is due not to lack of contributions, but to lack of funds. In addition to the greatly advanced cost of paper and engravings which has been in effect for the past two or three years, rates for composition and press work were advanced August 1, 1919, and again May 1, 1920, making a total increase of about 65 per cent. The total cost per page now is approximately double what it was four or five years ago. While there has been a steady increase in membership during the year, we are still well below the high point reached in 1917. I can see only one way to expand the Journal and make it a really representative publication and that is by increasing both

the dues and the membership. I believe that an increase from $2.50 to $3.00 a year is fully justified, and that this increase can be made without the loss of any considerable number of members. It ought also to be possible to obtain a large number of new members in 1921, as salaries are generally becoming better adjusted to the present value of the dollar, and there are numerous agronomic workers at almost every agricultural institution who ought to be supporting the Society. Even tho the JOURNAL is available to these workers in college and station libraries, they ought to have sufficient pride in their profession to make a small contribution each year to their organization and its publication.

The JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY is growing in prestige, as is evidenced by the new subscriptions which come in from time to time from foreign sources and from public libraries in the United States. These institutions not only order the current volume, but often place orders for several of the volumes published in previous years or even for a complete set. This fully justifies the policy of the executive committee in having printed a considerable larger number of copies than is required for current needs. Our income each year from the sale of back volumes, as shown by the secretary's records, runs fom $200 to $300, and this amount increases from year to year. The small additional cost of the copies in excess of immediate needs is much more than made up by the proceeds from future sales.

Respectfully submitted,

C. W. WARBURTON,

Editor.

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